D1.4 – Specification for the new Energy Management System for hybrid storage

WP1 – Requirements, Use Cases, Specifications

T1.4 – Specification for new generation of EMS software tools to achieve hybridization

Submission date: 31.10.2023

Project Acronym	INTERSTORE
Call	HORIZON-CL5-2022-D3-01
Grant Agreement N°	101096511
Project Start Date	01-01-2023
Project End Date	31-12-2025
Duration	36 months

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101096511. Disclaimer: The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

Information

Written By	Elyas Rakhshani, Francisco Marcelo Cano, Rafael Gonzalez Nieves (HES) Alexandre Lucas (INESC) Nikolaj Candellari, Peter Nemcek (CYG) Martino Alessandra, Guaraldi Francesco (ENX) Fabian Sommer, Martina Josevski (EAT)	2023-07-10 2023-08-08 2023-07-10 2023-07-30 2023-08-07 2023-08-07
Checked by	Alexandre Lucas (INESC) – WP1 Leader	2023-10-30
Reviewed by	Alexandre Lucas (INESC) Peter Nemcek (CYG) Nikolaj Candellari (CYG) Nithin Manuel (RWTH)	2023-10-25
Approved by	Project Coordinator - Prof. Antonello Monti (RWTH)	2023-10-31
Status	First formatted version 2.0	2023-06-20

Dissemination Level

CO	Confidential	X
CL	Classified	
PU	Public	

Versions

Date	Version	Author	Comment
08-06-2023	1.0	Elyas Rakhshani, Francisco Marcelo, (HES)	The first draft
20-06-2023	2.0	Elyas Rakhshani, Francisco Marcelo, (HES)	Updated version in project format
15-07-2023	3.0	HES and INESC updates	Sections update
15-08-2023	4.0	All the partners updates	Content updates
01-10-2023	FINAL	Elyas Rakhshani (HES)	Final and submitted version

ACKNOWLEDGEMENT

InterSTORE is an EU-funded project that has received funding from the European Union's Horizon Research and Innovation Programme under Grant Agreement N. 101096511.

DISCLAIMER

The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union. The European Commission is not responsible for any use that may be made of the information contained therein.

While this publication has been prepared with care, the authors and their employers provide no warranty with regards to the content and shall not be liable for any direct, incidental or consequential damages that may result from the use of the information or the data contained therein.

ABBREVIATIONS AND ACRONYMS

API	Application Programming Interface
BMS	Battery Management System
BESS	Battery Energy Storage System
ESS	Energy Storage Systems
CAN BUS	Controller Area Network bus
C&I	Commercial and Industrial sites
DEMS	Distributed Energy Management System
DER	Distributed Energy Resources
DES	Distributed Energy System
DERMS	Distributed Energy Resources Management System
DSO	Distribution System Operator
EMS	Energy Management System
EV	Electrical Vehicle
FFR	Fast Frequency Regulation
HESS	Hybrid Energy Storage System
HEMS	Hybrid Energy Management System
HyDEMS	Hybrid Distributed Energy Management System
INMS	Intelligent Node Management System
NILM	Non-Intrusive Load Monitoring
POD	Power Oscillation Damping
SoC	State of the Charge
SoF	State of the Function
SoH	State of the Health
SOA	State-of-the-Art
SCADA	Supervisory Control And Data Acquisition
TRL	Technology Readiness Level
TSO	Transmission System Operator
TCP	Transmission Control Protocol
VPP	Virtual Power Plant

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report aims to specify the functional and technical aspects of the EMS (Energy Management System), outlining its intended purpose and describing its interactions with other actors in a Hybrid system from an architectural standpoint.
Before starting with the design development, dimensioning and integration in the coming future work packages in the InterSTORE project, a clear picture of the current available technologies with their specifications is necessary to address the integration process towards the most appropriate and feasible way.
In this document, as part of the deliverables of WP1, the specifications of different EMS will be presented to identify how the EMS will be developed and how it will interact with other actors/components of the system.
This deliverable is the outcome of the Task 1.4 and it will provide the technical and functional specification of a new set of distributed energy management systems with the purpose of developing an open-source interoperable tool including the advanced protocol converter considering legacy systems for achieving a seamless integration of distributed energy storage resources, working all together as a virtual and hybrid energy storage system, working as agile, flexible, and singularly as a conventional battery energy storage system with extended capabilities. It should allow various DES, DER and several new generation Energy Management Systems (EMS) to be integrated by different stakeholders, while demonstrating the value added of asset's connection to common data space, reducing uncertainty and hence increasing acceptance by technology takers and final users. It will use beyond the state-of-the-art methods to enable hybridization, utilisation and monetisation of storage flexibility, while also ensuring data space standardization.
The new generation of energy management systems (EMS) will comprise platforms that individually control EV Batteries, Home Batteries, Industrial batteries and UCAPS, or connection with the Heat Pumps, as well as with the flexibility aggregation platform. The envisioned hybrid and distributed energy management systems that comprises the InterSTORE project, will have an agnostic energy storage approach, allowing the integration and the seamless operation of several distributed energy storage systems, with different power and energy capabilities, as a virtual energy storage system with extended capabilities in terms of flexibility services provision. This task will analyze and define the different software tools and algorithms that will allow the hybridization of energy storage and determining the capability of providing a pool of flexibility grid services.

The purpose of this deliverable in short is to:

i) provide a list of state of the function for different technological EMS provided for this project.
ii) Collect the generic specifications of each EMS technology.
iii) Provide list of variables to identify the system development.
iv) Provide a generic diagram and architecture of the newly developed EMS tool.

Structure of the deliverable:

- Section 1 presents an overview of the hybridization approach in the context of the project.

- Section 2 presents a review on the state of the art of the technologies providing EMS in the project.
- Section 3 reports the advances regarding technical specifications and generic architecture of the new EMS technology context of the project provided by the project partners. It also gathers preliminary lists of variables to characterize the system under development to determine performance indicators.
- Section 4 summarizes conclusions and lessons learned.
- Finally, sections 5, 6 and 7 present the references, list of tables, and figures of the deliverables, respectively.

1 THE HYBRID APPROACH

The goal of this section is to explain the hybridization concept on energy management system for hybrid energy storage solution. The hybridization approach in this project, depending on the use cases application, it can incorporate the different signals stating the current status of the storage component such as SoC, SoH or in general way the State of the Function (SoF) into the overall hybridization process for providing a more efficient performance with a seamless integration of distributed energy storage resources in large systems with multiple components. It helps with developing a new generation of energy management systems (EMS) which will comprise platforms that can individually control different sources of energy such as UCAP, Home Batteries, EV Batteries.

1.1 Hybridization concept

Battery cells are intensively tested by manufacturers under static standard profiles. However, there are high deviations in the performance when the technology is “packaged” into utility scale solutions and is operated under real mixed “power and energy profiles”, far from standard tests by manufacturer. Reliability decreases and batteries experiment a higher degradation than the expected under “power-profiles”, where peaks of power with a low amount of energy are frequently required.

For instance, while batteries provide high energy density, ultracapacitors offers high power density, avoiding an excessive degradation and oversizing of batteries. The use of a technology for providing a response with a higher power density requirement (such as an energy battery for providing a response of a few seconds or minutes) requires the installation of a high amount of energy than needed (as seen in the Ragone plot).

On the contrary, the use of a power technology for providing a high amount of energy involves an excess of power capability that is not used. The use of the proper technology or a combination of them for providing one or more stacked services avoids this oversizing.

Moreover, utilities are realizing that many of the issues to be dealt with under the new paradigm of the power grid will have this “power characteristic” with a fast-required response. Which means fast services are needed. Such as frequency regulation (Frequency regulation is a service in power systems that involves actively managing and stabilizing the grid's frequency to match supply and demand, ensuring a consistent and reliable electrical supply), virtual inertia (Virtual inertia is a power system technology that emulates the inertial response effects of traditional generation units such as synchronous generators, in grid-connected electronic devices using advanced control and energy storage techniques) that cannot be efficiently and effectively provided by traditional ways.

There are different technologies with different features. Likewise, there are different requirements for ESS depending on the grid integration application and the grid codes that are applied in the specific site.

There is not a single technology that covers both power and energy services in a cost-effective way, so traditional BESS approach often leads to non-optimal or even to unprofitable solutions. Thus, the role and the necessity of hybrid approach and hybridization algorithm, which can mix different technologies as shown in Figure 1, will be important especially for future grid scenario while various services are demanded by system operators.

Hybrid storage means "using the best of all worlds". A hybrid storage system combines different storage technologies leveraging their features and their synergies for obtaining a single solution that adapts to any type of application with power and energy requirements.

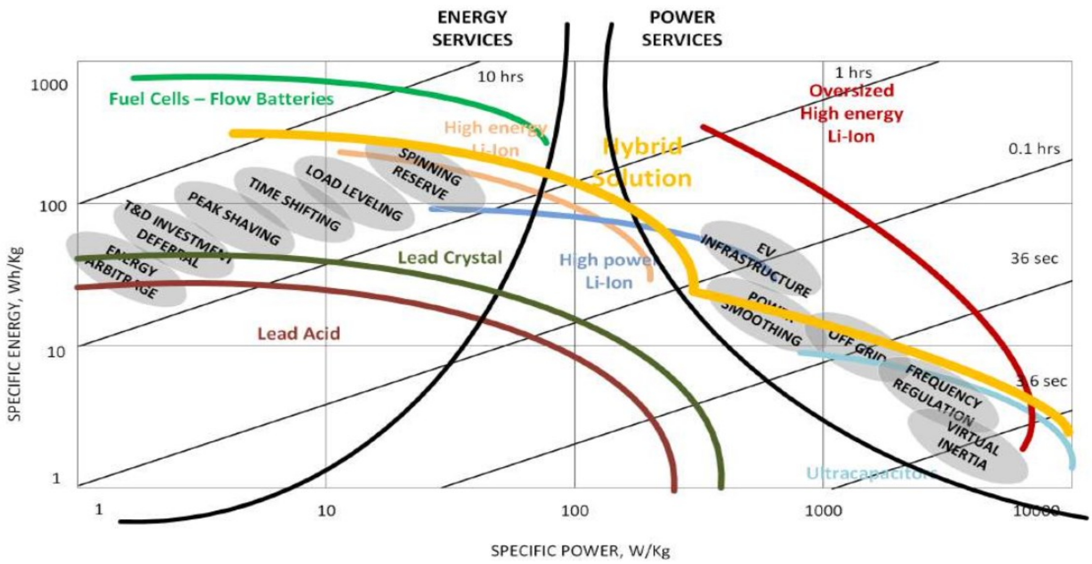

Figure 1. Hybrid concept, avoiding oversizing depicted over a Ragone diagram.

As shown in Figure 1, hybrid storage technology is mixing of different source of energy storage technologies for providing a wide range of solutions, from power based storage components to energy based storage system, covering the whole spectrum of possible hybrid power/energy ratios.

1.2 Base of a hybridization algorithm

In order to, explain the logic behind the hybridization, a generic example is presented in Figure 2 and Figure 3 is showing single/multi-level hybridization concept. Figure 2 shows the one level hybridization algorithm, where from the power profile reference that the HESS has to provide, the total response is divided by different distributed HESS system, (for example the energy/power battery and the UCAP/power battery or different combination), that is a combination of two basic kind of technology: energy battery, power battery or UCAP for covering wide range of services.

As a generic explanation, as shown in this figure, the power reference is divided in two signals, a low-frequency signal, and a high-frequency signal. In this way, the energy/power battery will oversee providing the low-frequency signal and the UCAP/power battery will be in charge of providing the high-frequency signal. In case of having more complex scenario with multiple storage, a multi-level/layer hybridization can be incorporated as shown in Figure 3.

For example, according to the schematic of Figure 3, at the Level 1, the received profile reference signal will be categorized, by hybridization algorithm, to separate low/very low frequency signal assigned to high energy-based storage component. Then the rest of the signal will be passed to Level 2. At the Level 2 of the Hybridization algorithm, depend on the available storage technology and needs of the use cases, the signal will be divided to very high/high frequency and low frequency. So, it can take the UCAP, as an example, for very fast response and power-based battery for slower services.

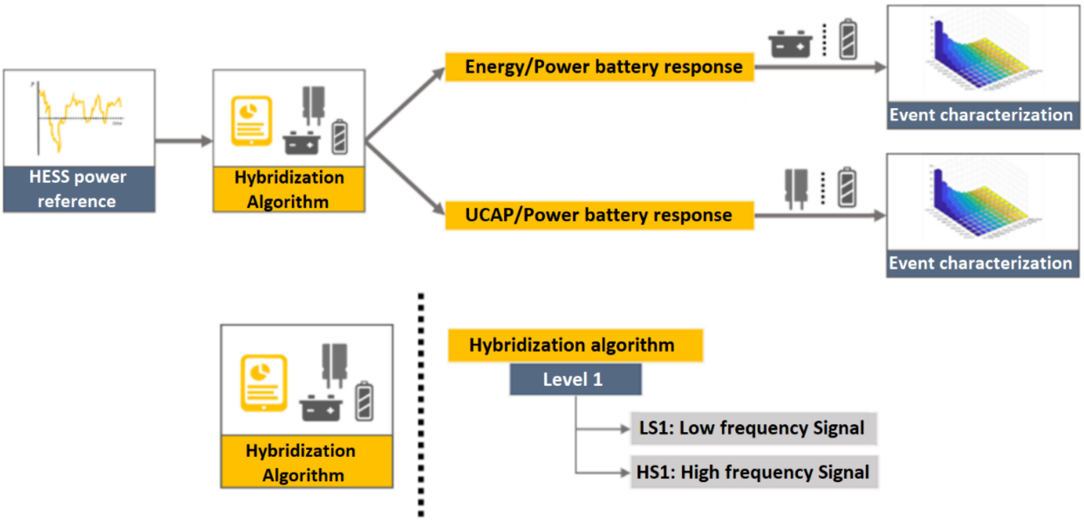

Figure 2. One level hybridization scheme

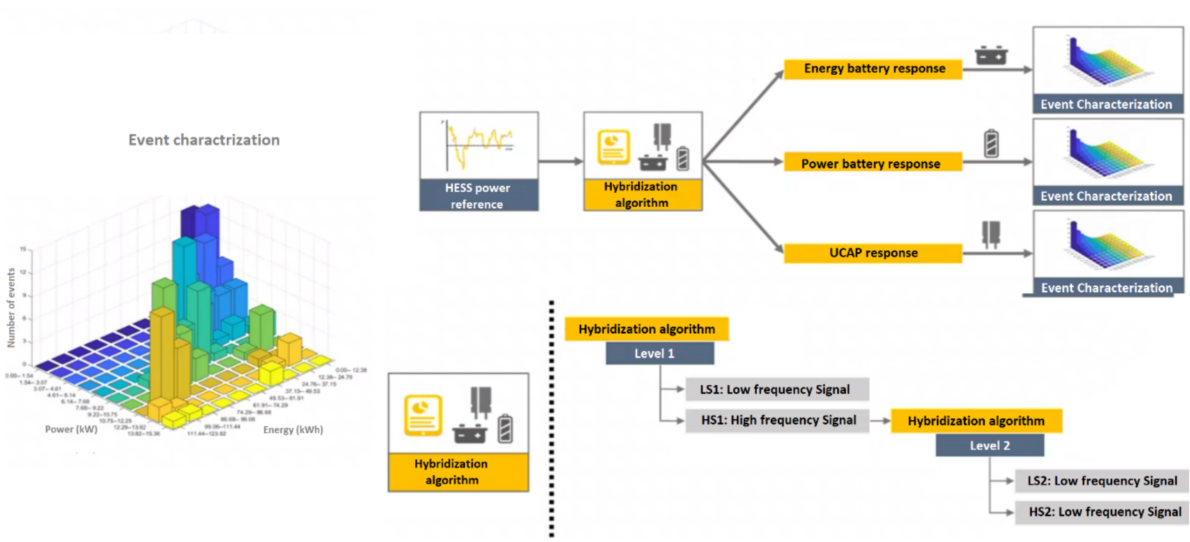

Figure 3. General view of a two-level Hybridization scheme.

Thus, thanks to the energy management tools provided in different use cases in this project like HyDEMS in UC7, this approach can be easily adapted to a scenario called multi-level Hybridization scheme which can act as one of the local software-based control layers, enabling hybridization and stacking services.

2 TECHNOLOGY BACKLOG

In this section, the focus is mainly on the technology backlog, to a comprehensive exploration of the state-of-the-art (SOA) aspects within the EMS (Energy Management Software) tool, as implemented by each of the technology providers collaborating on this project. By diving into the details of the EMS software, we aim to uncover the cutting-edge features, architectural elements, and innovative functionalities which will be embedded within these critical tools during the project. This part can provide a better understanding of the technological landscape while it can also serve as a foundation for our project's execution and advancement.

2.1 Flexibility management platform

During the last decade, flexibility management platforms (including virtual power plants and demand response systems) have become standard in the European power system. From a technical perspective, close to real-time pooling of distributed energy resources (DER) with simple boundary conditions, including remote control and cost optimized dispatch for the purpose of provision of flexibility to a power market can be considered as state-of-the art and several technical solutions can be found on the market. Aggregators like NEXT Kraftwerke, Enel X, Energy Pool, Viotas or Centrica (ex. ReStore) successfully aggregate third parties' flexibilities and trade flexibility products mainly on markets for ancillary services to the TSOs, where a high revenue can be expected. CyberGrid's flexibility management platform CyberNoc is a state-of-the-art software system, which has been used by aggregators and traders of flexible electricity in Austria and Slovenia since 2014. However, the lack of interoperability presents for all aggregators and technology providers one of the most common technological and economic barriers: the complexity and cost of connection between flexibility asset (DER) and aggregation platform. Furthermore, many flexibility management and aggregation systems offer none or very limited hybridization possibilities, focusing rather solely on particular type of flexibility, like demand response loads or Distributed generation or Battery Energy Storage Systems (BESS), although combining these various types among each other would bring significant technical and economic optimization improvements.

CyberNoc enables seamless integration of BESS and other flexibilities with multiple European electricity markets through standardized interfaces. Fragmented energy markets cause long lead times for storage projects and thus decreased Return on Investment (ROI). Seamless access to multiple markets provided by CyberGrid is also a prerequisite for efficient arbitration after BESS projects have already been deployed. Furthermore, it ensures that BESS can be applied to a multitude of business use cases, some of which can be operated at the same time. For example, BESS at Commercial and Industrial sites (C&I) can be operated to decrease the peak power, ensure power quality, and security of supply (i.e. back-up services). This same BESS can be used to provide storage for energy produced from renewable sources (solar, wind). In the night-time it can again be used for ancillary services markets. Similar combinations involve BESS facilities at e.g. communities and municipalities, and large-scale grid storage.

Conceptual diagram of Flexibility Management Platform CyberNoc is presented in Figure 4.

Figure 4. Concept diagram of Flexibility Management Platform CyberNoc

Until now BESS have been typically connected to one of the specific applications, for example storing of renewable energy, provisioning of power quality, providing backup services, peak power management or provisioning of ancillary services. Furthermore, most large stationary BESS deployments across Europe are connected to supply of primary reserve. Since these markets are relatively shallow, prices are subject to volatility. Combined with long-term nature of BESS investments their owners are exposed to significant risks. CyberNoc's advanced algorithms opens several combinations (e.g. multi-services) and additional options in various markets. It combines a large number of energy assets, so called "flexibilities", into pools. The flexibility assets include distributed power plants, loads and renewable energy plants. CyberGrid's flexibility management platform pairs BESS with these pools; such hybrid pools have superior technical and economic characteristics when managed by CyberNoc, which is the CyberGrid proprietary advanced algorithms and connected to various electricity markets.

CyberNoc is also highly scalable. It is built on its cutting-edge, micro-service architecture. Micro-services are independently deployable and organized around business capabilities. Micro services in general can be implemented using different programming languages, databases, hardware and software environment, depending on what fits best. Modularity allows CyberNoc system to add or take away functionalities (modules) as needed. The platform can create tailor-made solutions for customers/markets such as the integration of third-party modules and customization to special business cases or markets.

2.2 Hybrid Distributed Energy Management Systems

There is a wide variety of DERMS in the market that although they have a high technological level in terms of software, they still lack an in-depth knowledge of base technologies, mainly energy storage systems. Most renowned platforms are Greensmith's GEMS system, Athena by Stem, ABB Ability, Itoms or Johnson Controls platforms. Compared with HyDEMS, HES's TRL6 distributed energy management system, these products, and their algorithms lack of high skills regarding the know-how about the performance, degradation and capabilities of the base technologies and energy storage integrated in the grid. The hybrid approach, the integration of degradation and operation models of energy storage and the virtualization feature of the HyDEMS permits to cover a wide range of scenarios and applications; configure multiple optimization targets for different flexibility services.

In HESStec, an advanced EMS called InMS has been used in different projects, like HYBRIS[1] for optimal managing different services. As shown in Figure 5 , InMS is a hardware and software control platform integrating proprietary algorithms, oriented towards an optimal planning and multi-service operation by the end-user based on a deep know-how of the storage technologies and their performance into real grid scale applications.

This is the Energy Management System (EMS), that can be configured for different applications, from off-grid (island) to grid-connected applications with external communications with the SCADA of DSO/TSO or connection to energy market platforms. An updated version of this tool (HyDEMS) will be implemented for Intersotre project.

Figure 5. Intelligent Node Management System and User Interface

2.2.1 Functionalities

InMS platform offer two main functionalities:

- Business model generator and sizing tool, as a planning tool for the system designer and end-user, that allows to configure the SHAD® solution (patented technology from HESS-tec), defining the hybridization ration and sizing the main elements as a function of the scenario, services to be provided, regulations, etc. It is based on behavioural and degradation model and allowing the operation of the system in its whole service life. Besides the sizing, the tool provides the most profitable business model, including all the economics.
- Optimal management system tool, for the real-time operation of a grid/microgrid where multiple services can be providing by various assets, including hybrid energy storage,

[1] HYBRIS EU H2020 project: https://hybris-project.eu/

based on SHAD® technology. This is the Energy Management System (EMS) or Power Plant Controller of HESStec.

The InMS technology has three application versions depending on the purpose in its use and whoever is its operator:

InMS-SHAD® control and hybridization of hybrid energy storage solutions.

InMS-uGRID: control and management of a microgrid composed of different assets, including hybrid energy storage solutions (which may be governed by its own InMS-SHAD®).

InMS-DISTRIBUTED: distributed control and coordination between several InMS (each governed by its InMS-uGrid or InMS-SHAD®) without total or partial need of a centralized system.

The use of the same InMS technology for different applications and operation schemes is possible thanks to the implementation of a virtualization layer that gives the design a modular characteristic, which can be applied in different scenarios and with the inclusion of different technologies.

2.2.2 Services

The physical elements that comprise the HW/SW InMS platform can be found inside the boxes shown in Figure 6. .

At hardware/software level, Real-Time Control and Communications System hosts the real-time execution algorithms (fast dynamics, hybridization, etc.), including the virtualization given by the SoF, which provides the system with the appropriate interfaces for a high interoperability and supply. The necessary analog and digital channels for the measures and command signals required.

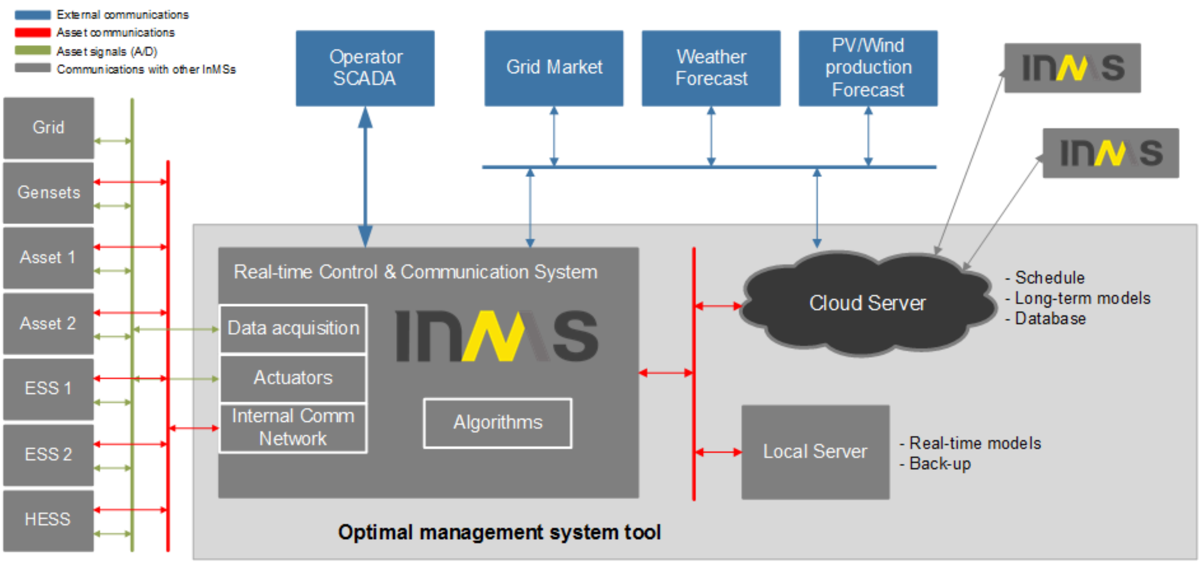

Figure 6. Scheme of the InMS Optimal Management System Tool.

It also includes an architecture of local/cloud servers that support the operation and optimization of the system. The server in the cloud hosts the databases and algorithms with slower dynamics, such as daily planning and updating of Advanced Asset Models, both in behavior and degradation, through self-learning techniques such as Machine Learning. This server in the cloud also includes the management of the subscription to forecasts of time and production of renewable generation.

The local server implements the advanced real-time asset models as well as the hourly operation algorithm and the correction of deviations with respect to daily planning.

Thanks to the hierarchy with fast communication system, various integrated power and energy services can be provided. Fast and power-based services with high-speed energy management platform with time response less than 100 ms:

- Black start capabilities
- Island mode and grid connected mode operation with fast synchronization
- Grid forming and grid following mode of operation of HESS conversion system
- Inertial response services (Virtual inertia)
- Fast frequency regulation (FFR)
- FSM/ LFSM modes/ FFR secondary reserve service
- Power oscillation damping (PODp and PODq)
- Voltage dip regulation and reactive power support
- Active power and reactive power control with hybridization
- Fast peak shaving services
- Arbitrage (Diary and Intraday markets)
- Time shifting
- Ram Rate control
- Techno-economic optimization
- Power smoothing and ram control
- Specified service combinations.

This EMS tool is upgraded with more advanced added value functionalities, including incorporation of SoF as the figure of merits of the whole hybrid system, to a new EMS tool called HyDEMS for the use of InterSTORE project. As it will be explained in Section 5, HyDEMS would be able to visualize seamless integration and optimization of different energy resources in a distributed scenario. HyDEMS will comprise a set of proprietary hybridization, degradation, and virtualization algorithms, oriented towards an optimal planning and interoperable distributed energy storage (DES) operation with the final purpose of enabling the provision of a stacked pool of multiple flexibility services to grid operators.

2.2.3 Communication hierarchy

To perform an optimal service, the best protocol available in the selected assets, power electronics, Gensets, PV, etc… can be chosen.

The hierarchy presented in Figure 7, is an example of implemented protocols in different national and international projects.

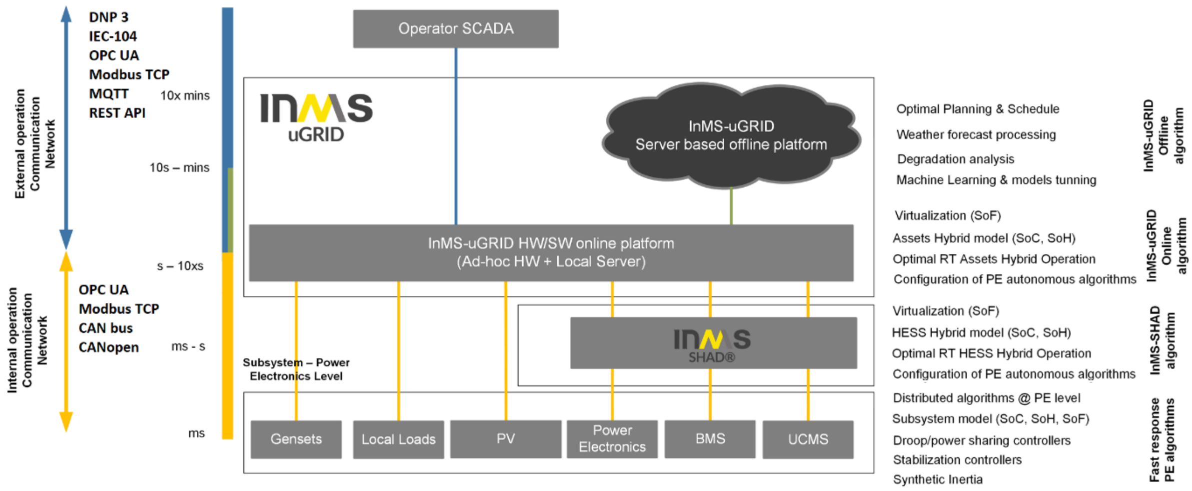

Figure 7. Hierarchy of communication levels for HyDEMS.

1. Internal operation communication:

   For fast services the crucial communications InMS -> power electronics, we need to grant communication delay smaller than 50ms.

   - CAN bus/CANopen < 10ms.
   - MODBUS TCP <50ms.

   For monitoring purposes and energy services, the protocol selection is less crucial, we can select any protocol with a communication delay 200ms or less.

2. External operation communication:

   For service parametrization, activation and monitoring, we need a protocol with a communication delay less than 1000ms.

   - OPCUA for 100 ms applications
   - Rest API for up to 200 ms applications

2.3 Home Energy Management System

The Home Energy Management System (HEMS) by Inesctec is a household level energy management system. It offers a set of services mainly for consumers, but also for Retailers, DSO and aggregators. Running remotely at InescTec servers, and in some cases locally, the services are added modularly as the system develops and matures. Beyond the backend algorithms it has a specific front end as a mobile app (Hems connect) whose main goal is to, show, inform, manage the energy consumption of a household and optimize the different eligible loads. At the time of writing, the latest version of the HEMS is being applied to the InterConnect European Project, where mostly the new additions related to interoperability were added.

This following subchapter contains the description of all the software development processes that encompass the system, from high-level architecture diagrams to service-specific use cases.

2.3.1 Different blocks of the HEMS infrastructure

HEMS infrastructure has several blocks for different purposes, summarized as follows:

- Kubernetes Infrastructure ➞ HEMS Kubernetes infrastructure configuration files for the production environment.
- Kubernetes Infrastructure Staging ➞ HEMS Kubernetes infrastructure configuration files for the staging environment.
- Gitlab CI Base Image ➞ Docker image pre-built using a GitLab runner as a base docker image for the HEMS services.
- Dev Portal ➞ Development Portal web page to access backend resources. Such as, swagger documentation, database UI etc.
- Privacy Policy ➞ The HEMS privacy policy.
- Kafka Connect Custom ➞ Debezium Kafka Connect image with custom plugins.
- Custom HEMS Libraries
- Hems Auth ➞ Library to standardize the authentication process for the HEMS application.
- SSA Management Library ➞ Library that streamlines the SSA workflows.
- Tutorials
- SSA Working Example ➞ Tutorial on how to use the SSA Management Library to develop a SSA. Includes branches with working SSA examples for project partners (such as, E-REDES, CyberGrid, Thermovault and Whirlpool).
- Counter Service Python Example ➞ Hands-on tutorial on how to develop a HEMS service using Python.
- Counter Service Golang Example ➞ Hands-on tutorial on how to develop a HEMS service using Golang.

2.3.2 HEMS Services

At the time of writing the HEMS has the following services available:

- Account Manager ➞ Service to manage user accounts and details for the HEMS app.
- Device Manager ➞ Service that manages the devices/cycles of HEMS users.

- Energy Prices ➞ Service that keeps track of the energy prices of the HEMS users.
- Incentive feed (Energy Prices/environmental) API ➞ Web API from Sentinel (InescTec third party platform) and ENTSOE webpage.
- Energy Manager ➞ Service to manage the schedules of a HEMS user.
- Flexibility Service ➞ Service that converts the grid's flexibility needs into an optimal consumption schedule, using CO2 emissions/tariffs predictions as incentive.
- Statistics Manager ➞ Service that manages the statistics/KPIs shown to the users/developers.
- Notification Manager ➞ Service to manage the notification on the HEMS mobile app.
- Grid Observability ➞ Service to monitor grid usage and faults.
- OpenAPI Swagger UI ➞ UI for the Swagger documentation on the service's requests.
- Forecasting Services ➞ Load consumption forecast module
- Forecast Kafka ➞ Forecast modules that make use of Apache Kafka. Includes, train forecast models, collect raw measurements and forecast producer.
- Data Disposer ➞ Processes the raw measurements collected from installations.
- Weather ➞ Weather forecast for a certain grid area.
- Metrics ➞ KPI module for the forecast services.
- Rest API ➞ Rest API to interact with the forecasting services.
- HEMS App ➞ Mobile app code and general assets
- EOT Temporal Monitor ➞ Temporal workflow to stream energy consumption data from dongle to the influx DB
- Graph Pattern Visualizer ➞ Web visualizer of Graph Patterns

For the InterSTORE project, the following features will be used:

Incentive feed – Will be used in both UC 5 and 6 to retrieve the day-ahead prices and gCO_2/kWh to perform a load optimization of the batteries. This is fetched from a third party platform called Sentinel by InescTec.

Flexibility Service – An adaptation of this service will be used to determine the potential flexibility available by the monitored assets (EVs and Batteries) and provide recommendations to the users accordingly. It will be further developed in InterSTORE and resented in D4.1

Forecasting Services – The load forecast of the building in UC5 and EVs in UC6 will provide inputs for the load optimization and flexibility estimation. This feature will be used adapted to InterSTORE, for the sake of computational cost, since the Demo will only contemplate one building and the original module is prepared to handle thousands of houses in different regions.

Weather – The weather forecast is implicitly used for the forecast services, making use of the location of the pilot site and determining the expected weather conditions influencing the energy consumption.

Rest API – All the interactions with the services will be made in python making use of REST API communications, with the support of the swagger documentation available in the HEMS repository.

The HEMS load forecast module will be used in InterSTORE and can be briefly explained as follows. It is based on a python implementation, and it runs on a server. The interaction is ensured by REST APIs. The following are the key players involved in this process:

- User-RESTAPI: This is the primary interface where requests from external users or systems come in.
- User: This represents our direct user who interacts with the API.
- HEMS-RESTAPI: This serves as the communication bridge between the user and our HEMS application.
- HEMS-APP: This is the core application where all the processing happens.

With these key players identified, the workflow is described as follows:

Firstly, Registering Installation Details & Forecast Configurations:

- Using the *0_register_service.py* script, the User sends an HTTP POST request to the /hems/registerService endpoint. This request includes vital details about the installation as well as PV & Load forecast settings.
- Once received, the HEMS-RESTAPI forwards it to the HEMS-APP for validation.
- Upon successful validation, the HEMS-APP updates its internal settings file and acknowledges with an 'Ok' message, letting the user know that everything has been set up successfully.

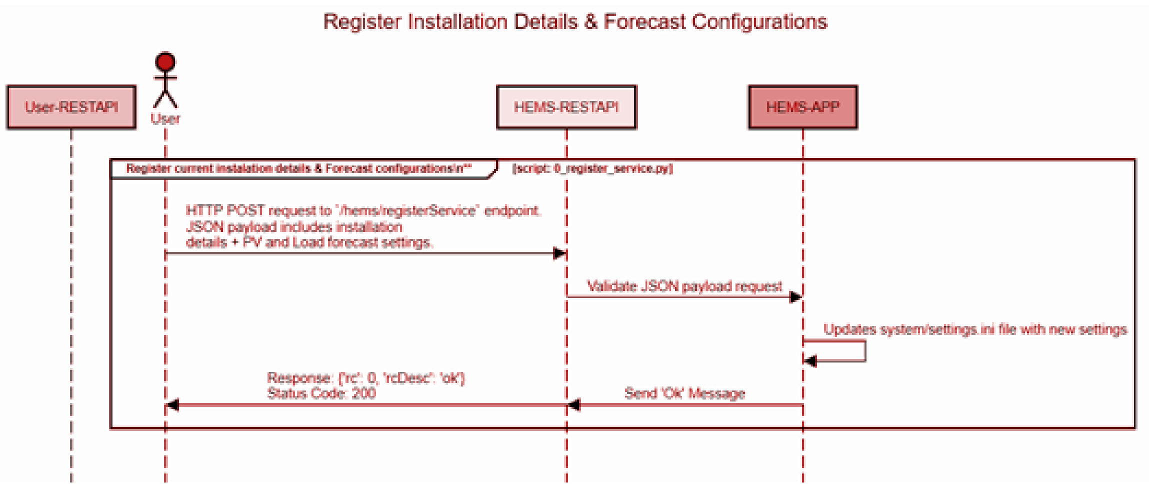

Figure 8. Registering the details and forecast configuration.

Moving on to Numerical Weather Predictions or NWP:

With the *1_request_weather.py* script, the User requests weather data by sending an HTTP GET request to the /hems/weatherRequest endpoint.

- Once this request is validated, the HEMS-APP initiates the downloading process for the NWP data. It might take a few minutes depending on the data size.
- Once retrieved, this NWP data is promptly saved in the database as well as sent to the user's designated REST API via a POST request.

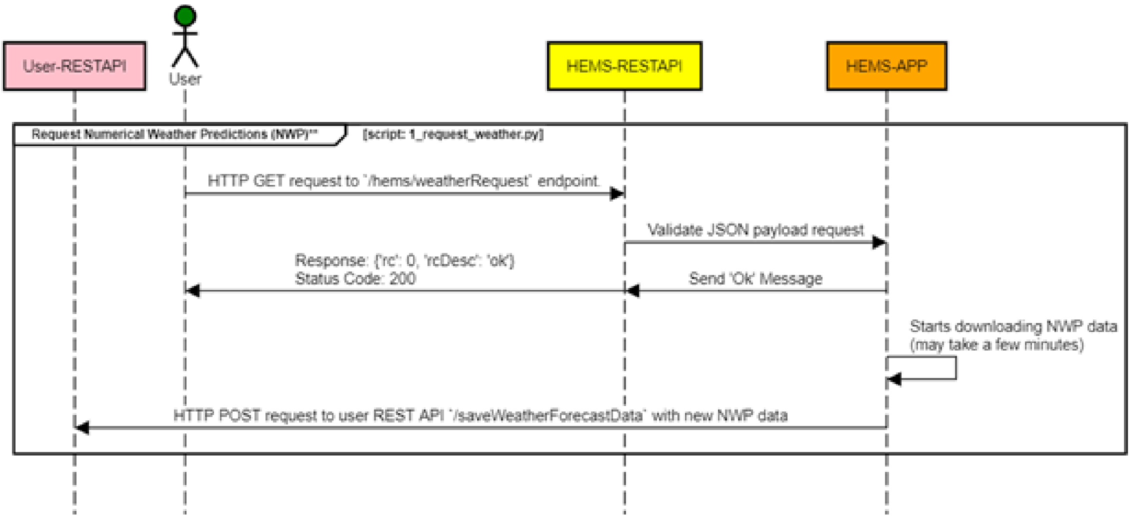

Figure 9. Request weather

Finally, Requesting the Load Forecast:

This step involves the *1_request_load_forecast.py* script. In this step, the User preps a JSON payload. This payload comprises two crucial pieces of information: the NWP data and the average power consumption details.

- It's essential to understand that for historical data, we need matching timestamps for both the weather prediction and power measurements. This ensures accuracy in our forecasts.
- For future forecasts, we only need the NWP data.

- Once the User sends this data through an HTTP POST request to the /hems/loadForecast/forecastRequest endpoint, the HEMS-APP jumps into action. It uses this data to fit a new Machine Learning regression model.
- After model training, the HEMS-APP computes load forecasts based on a predefined time horizon. The generated data is then sent back to the user's REST API.

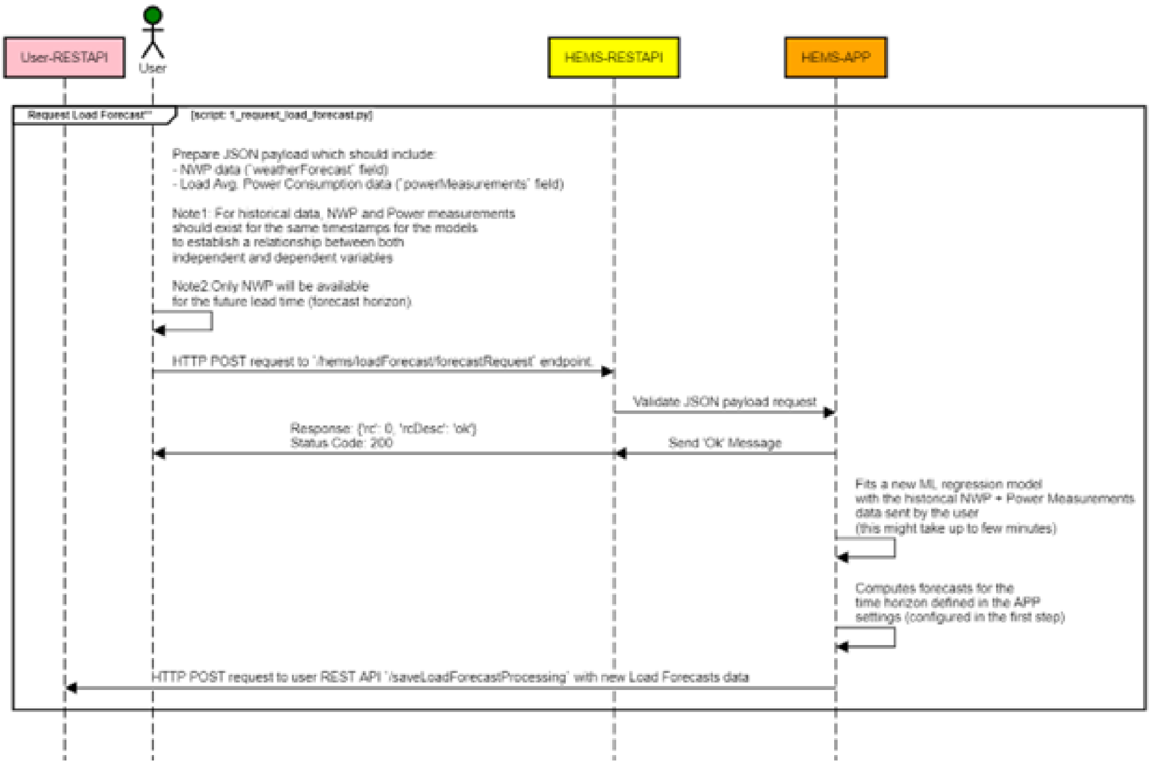

Figure 10. Load forecast.

An example of the output is presented below, with the id column is the index corresponding to each of the following 24 hours in the time stamp, the value corresponding to the forecasted load value in kW and the created at column showing when the forecast was requested.

id	value	quantile	timestamp	created_at
1	52.2315	q50	2023-08-28 13:00:00	2023-08-28 14:37:11
2	71.1253	q50	2023-08-28 14:00:00	2023-08-28 14:37:11
3	49.3902	q50	2023-08-28 15:00:00	2023-08-28 14:37:11
4	38.6156	q50	2023-08-28 16:00:00	2023-08-28 14:37:11
5	35.2825	q50	2023-08-28 17:00:00	2023-08-28 14:37:11
6	34.871	q50	2023-08-28 18:00:00	2023-08-28 14:37:11
7	32.2148	q50	2023-08-28 19:00:00	2023-08-28 14:37:11
8	30.0853	q50	2023-08-28 20:00:00	2023-08-28 14:37:11
9	31.0713	q50	2023-08-28 21:00:00	2023-08-28 14:37:11
10	33.5246	q50	2023-08-28 22:00:00	2023-08-28 14:37:11
11	31.9033	q50	2023-08-28 23:00:00	2023-08-28 14:37:11
12	30.9377	q50	2023-08-29 00:00:00	2023-08-28 14:37:11
13	31.4219	q50	2023-08-29 01:00:00	2023-08-28 14:37:11
14	30.106	q50	2023-08-29 02:00:00	2023-08-28 14:37:11
15	31.5843	q50	2023-08-29 03:00:00	2023-08-28 14:37:11
16	30.2872	q50	2023-08-29 04:00:00	2023-08-28 14:37:11
17	31.1241	q50	2023-08-29 05:00:00	2023-08-28 14:37:11
18	31.3038	q50	2023-08-29 06:00:00	2023-08-28 14:37:11
19	32.2325	q50	2023-08-29 07:00:00	2023-08-28 14:37:11
20	30.1167	q50	2023-08-29 08:00:00	2023-08-28 14:37:11
21	31.3378	q50	2023-08-29 09:00:00	2023-08-28 14:37:11
22	39.5532	q50	2023-08-29 10:00:00	2023-08-28 14:37:11
23	71.4244	q50	2023-08-29 11:00:00	2023-08-28 14:37:11
24	99.218	q50	2023-08-29 12:00:00	2023-08-28 14:37:11

2.3.3 HEMS High-Level Architecture

The HEMS is designed to be a modular and scalable microservice event-driven solution. As such, it uses *Kubernetes* to orchestrate services for its different features:

- The solution's services
- Relational and IoT databases
- Centralized logs
- Cluster resources monitoring tools
- System and Data Backups
- Tracing requests
- Service Mesh
- API Gateway

Figure 11 presents the block diagram of the HEMS and the use of supporting software/tools to enable the services.

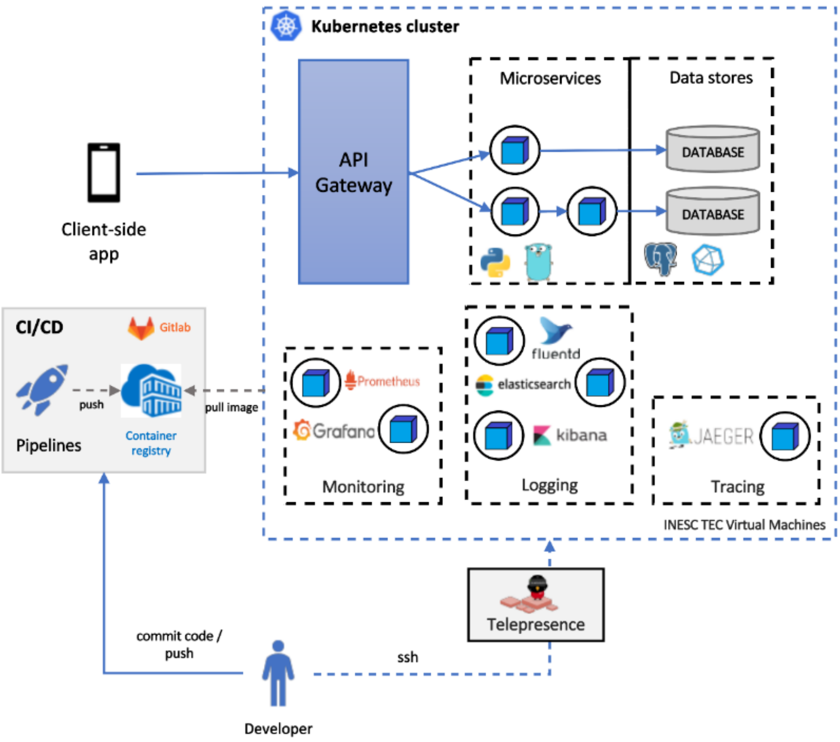

Figure 11. Block diagram of the HEMS with supporting tools.

2.3.4 HEMS Microservices Overlook

Figure 12– Presents the block diagram of the services provided by the HEMS in the context of user interaction back end in five domains: User account, Energy domain, Device domain, Statistics, Monitorization

The user is itself an important factor in providing information to the system, since at the beginning of the configuration of the HEMS Connect app, it is asked to insert several parameters. These include, contracted power, energy tariffs, location, a HEMS_ID to be matched with meter CPE and appliances clouds if it applies, among others. It has also to insert the appliance category and specific settings it wants to monitor and optimize.

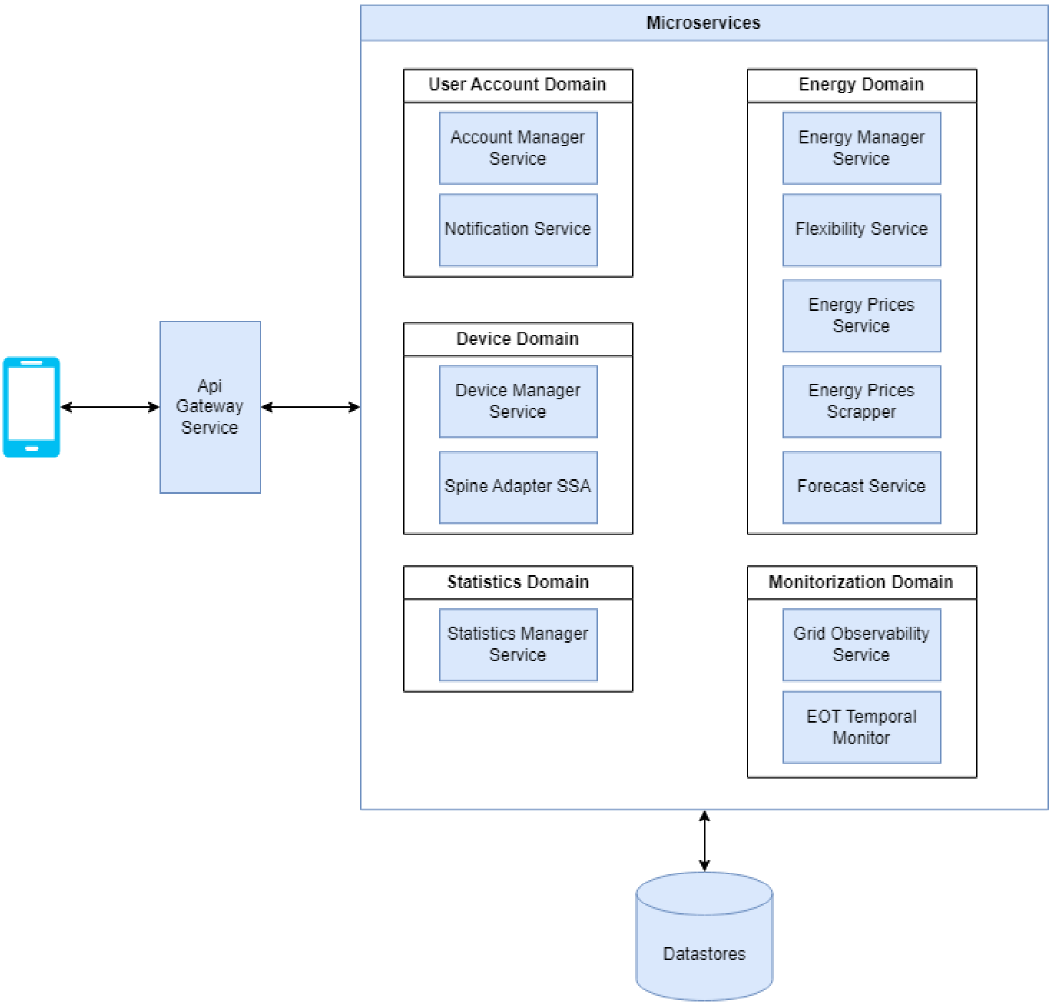

Figure 12. Block diagram of HEMS microservices divided by domain.

The HEMS Connect app has itself several screens and can be found in app stores such as Google play. An example of 6 screens of the app is show in Figure 12 and Figure 13. From the left top to bottom right, the use is capable of scheduling its inserted appliances, monitor daily consumption in energy and power rates, hourly energy consumption hourly for a chosen day, settings menu, Demand response prices and emissions incentives and add appliances screen with configurations.

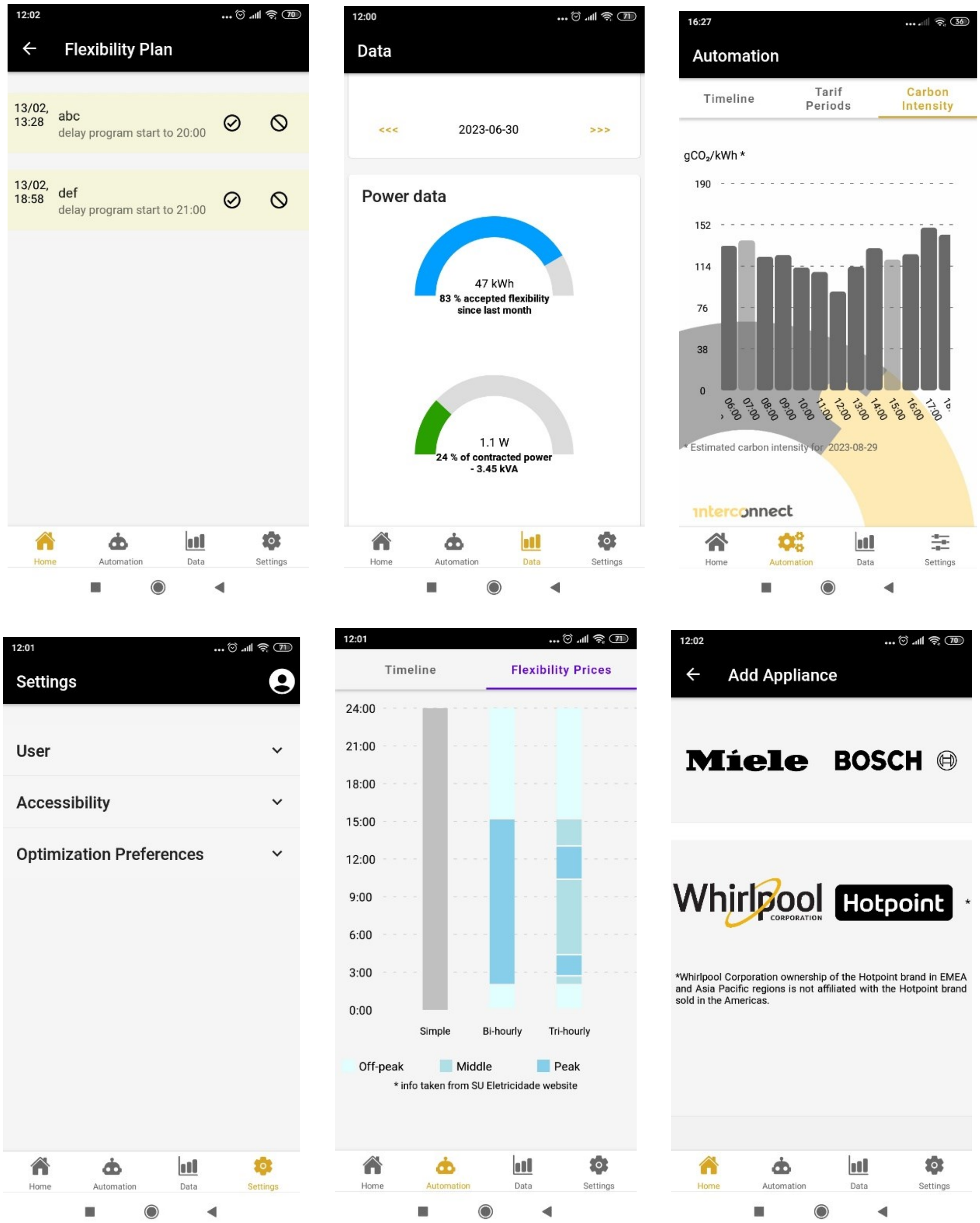

Figure 13. Set of available screens as an example in the HEMS Connect app

2.4 Hybrid E-mobility Management Platform

2.4.1 Flexibility Platform evolution

InterSTORE will contribute to the advance the current DES & DER offered by ENELX, by leveraging the standardised protocol to increase the number of supported hybrid DERs (e.g. PVs, load, BESS, and EVs.).

The VPP Flex platform allows the management of different types of flexibility products within the same hybridized portfolio. The most common use case up until now was a combination of industrial demand response loads.

The recent increase of BESS installations in C&I and residential market and the increase of EVs installations is an opportunity for integrating these new assets with other flexible assets, thus enabling more optimal combinations of complementary flexible assets. Incorporating these additional assets will result in better market utilisation, efficiency, monetisation and the possibility to enlarge the portfolio of Flex market products.

In the InterSTORE project, enhancements to the VPP Flexibility Platform and additional capabilities for the Asset Manager platform will be developed. For example, the Asset Manager platform will integrate using IEEE2030.5 Protocol interface.

2.4.2 Current Flexibility Management Capabilities

Enel X Flex selected capabilities include:

- Offers tools for portfolio management, including the ability to aggregate availability
- Can manage and dispatch hundreds of connected devices in parallel
- Helps coach customers during an event
- Calculates performance and telemetry in near real time
- Calculates settlement and provides energy insight
- Manages capacity markets, ancillary services and frequency regulation programs

In this project, Enel X Flex will submit offers on behalf of the group of the storage flex assets and pass the dispatch signal to those assets management software during an event.

Figure 14. Example of Flex platform data by Enel X.

2.4.3 High level architecture evolution

Currently, the flexibility software platform is implemented so that it understands devices on an individual level and communicates with them directly (via Enel IoT). With the InterSTORE initiative, we plan to evolve the current VPP Flex architecture by introducing the capabilities of managing aggregated assets (Flexible assets) and different typologies of devices. The concept of the Asset Manager allows Enel to decouple the flexibility requirements from the specific asset typology. The VPP platform must handle different flexibility market product rules and account for the heterogeneity of assets.

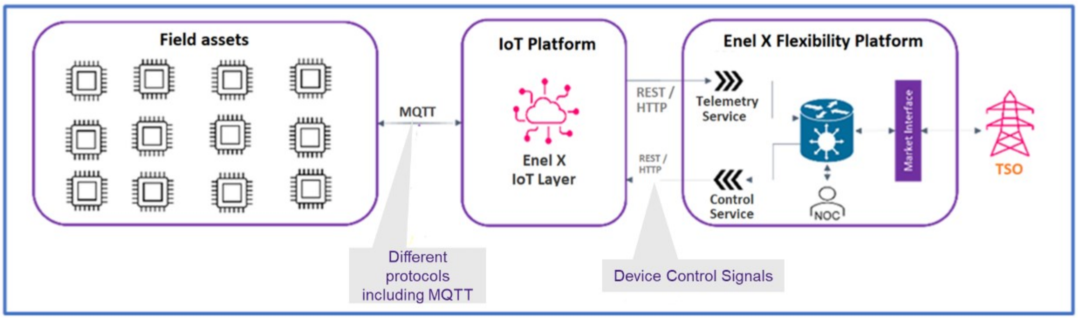

Figure 15. Current Flex Architecture

As shown in the Figure 15, the current architecture manages single devices through the Enel IoT platform.

3.4.4 Future Flexibility Management Platform

Within the InterSTORE project, the Platform will evolve to Hybrid Management Platform with the introduction of the concept of VPP (Virtual power Plant) Manager and the Asset Manager. In this case, as shown in Figure 16, the VPP Flex platform will have a new level of abstraction thanks to the Asset manager, and the VPP Flex platform will become independent and more scalable from the specific device typology. Detailed explanation of such advancements for this project is presented in Section 4.4. In Section 4.4, you will find a comprehensive and intricate exposition of the innovative strides made in this project, offering a detailed account of these advancements to further enhance your understanding.

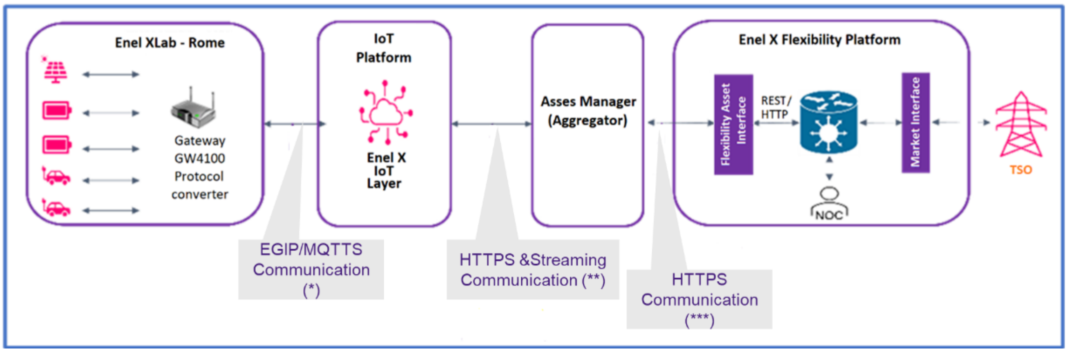

Figure 16. Future Flex Architecture

With this architecture, it will be possible to build a business portfolio that leverage on different kinds of devices to satisfy the market needs and to achieve the highest revenues from Flex Services.

(*)

- EGIP -> Enel Global IoT Platform. Conceived in 2017, supports connectivity and edge-computing globally. It is an Open, modular and secure platform which implements the following Capabilities: Acquire data from real world, Manage device fleet and onboarding, Send and receive command Enforce communications security OTA and Remote Control Rule Engine and device monitoring.

- Mqtts - > Message Queuing Telemetry Transport Secured. This is a protocol designed to support connections with resource constraints or limited network bandwidth. This is used by EGIP to manage device lifecycle, retrieve telemetry data and send commands to devices. Further information on this protocol are reported below [3.5]. In this scenario, devices act both as subscribers (to receive commands) and publisher (to send data). In Platform there is a serverless layer who forwards telemetry messages and collects and prepares command messages sent from Asset Manager.

(**)

- HTTPs and streaming connection. There is a Kafka broker [3.6] between IoT Platform and asset manager to support telemetry data streaming and command. IoT platform acts as a producer whereas Asset manager as a consumer of telemetry messages. Commands are received by IoT Platform through APIs. Completion status of commands are sent through kafka broker.

(***)

- The flexible Asset Interface (FAI) is a set of Standards that defines all interactions with the VPP Manager and the participating flexible assets. The standards consist of a set of APIs, events and protocols. For Interstore scope they will be only over Hypertext Transfer Protocol Secure (HTTPS)

2.5 Residential Power Management System

2.5.1 Building as a Grid concept

EVERYTHING AS A GRID is Eaton's approach to reinventing the way power is distributed, stored and consumed. With advanced technologies and digital intelligence, we are unlocking a low-carbon energy future for all. Buildings are becoming energy hubs. Building owners and operators need to be prepared for the future and meet new regulations – design future buildings, integrate EV chargers or leverage renewable energy produced on site while managing the energy flows and planning power capacity.

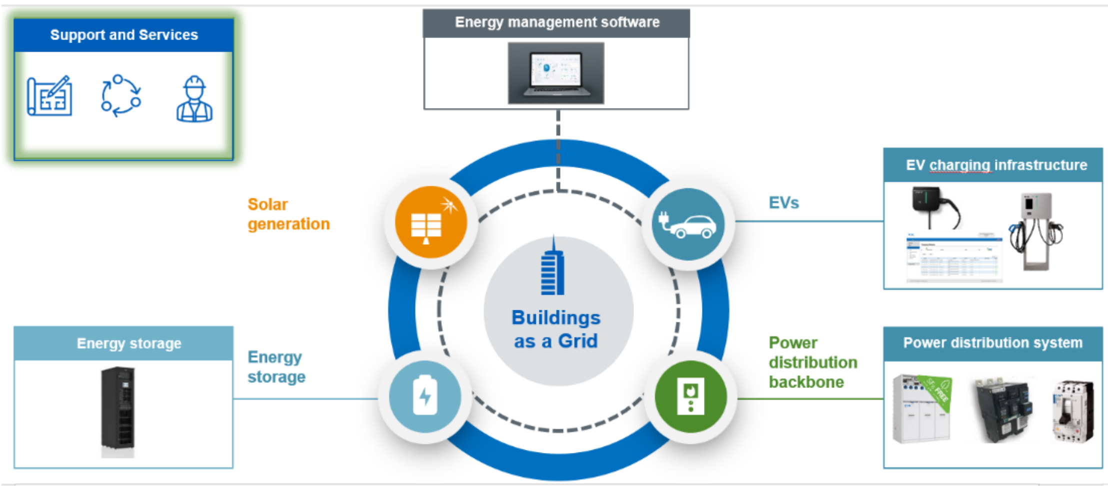

Figure 16. Building as a Grid concept

Eaton is proposing an integrating power management platform in a building, both residential and commercial. The distributed sources and loads are connected with a common control system, and their operation is managed for maximizing the benefits to the users and the wider energy infrastructure. This approach is defined as Building-as-a-Grid concept, as shown in Figure 16. It integrates all the building electrical assets, such as distributed resources (EV, PV, storage), as well as the Energy Management Software and associated services. Figure 17 shows an example of a building setup.

The Energy Management System (EMS) for residential/commercial buildings is part of Eaton's Brightlayer platform and is needed to help the building manager reduce energy costs and CO_2 emissions by collecting and analysing data, predicting and controlling energy flows. The Brightlayer platform offers a comprehensive software solutions and services targeted to key industries/applications such as utilities, data centres, industrial production and buildings. The digital platform leverages a range of technologies including cloud, edge technology as well as cybersecurity and data science concepts to provide data services, knowledge & data layer and algorithm libraries.

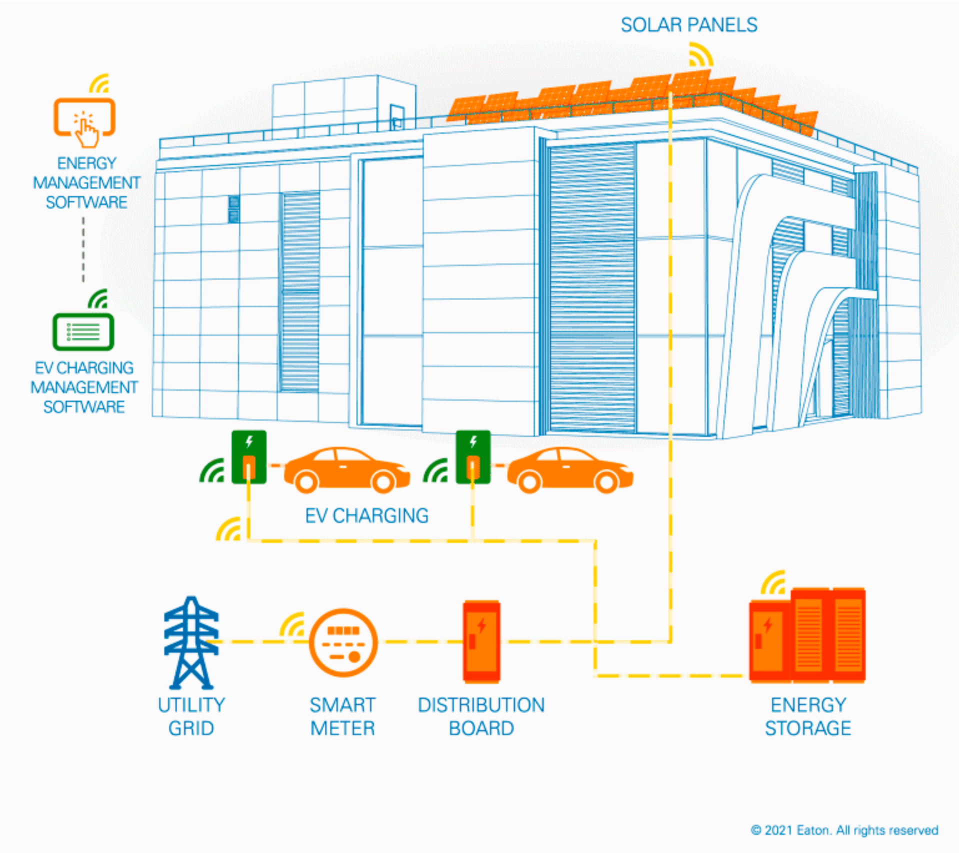

Figure 17. Building setup example, with Eaton Brightlayer BEMS integrating storage, PV and EV

2.5.2 Current capabilities of the Building Energy Management System

At the current maturity stage, the building EMS provides optimization & control of energy assets for the next 24-hrs, such that the use of renewables is maximized while simultaneously electricity bill and environmental footprint are reduced with limited or no impact on business performance and user experience. For residential buildings and offices EMS is designed to optimize the flexibility assuming that some or all the following energy assets are available: Eaton Green Motion EV chargers, PV panels and xStorage Compact battery packs (see Figure 17).

Figure 18. Energy Management System basic capabilities - EATON.

The main functions of the building EMS are:

1) Monitoring

The parameters of the connected assets are measured and recorded, so that the building user or operator can identify the main building consumers and the local generation, to decide the available optimization approaches, which will be implemented also by the Building EMS.

2) Forecasting

The system is using local historical data, as well as available data from other sources, to predict the potentially available system resources and consumption patterns. The building power consumption is estimated, and the optimal settings are calculated and used in the following periods.

3) Optimizing

The system is using the user input and forecasting results to apply the right settings for reaching the optimal output parameters, including total energy consumption, maximum power peaks demand from the public grid, energy bill and system operational cost, minimizing battery degradation, or other optimizing criteria.

4) Reporting

The system parameters, including the settings and the electrical output (voltage, current, power profiles and energy consumption), are recorded and included in reports that can be generated periodically or by demand. For commercial buildings the first proof of concepts has been made where EMS, apart from insights into energy usage, provides indication of the health of energy assets to reduce the equipment downtime.

Integration of the 3rd party hardware (like heat pump) and/or software components is currently not enabled. There is also a need for a standardised, interoperable EMS solution that would allow the application of other storage technologies and aggregation with other storage application in the scope of distributed energy management system (DEMS).

3 GENERIC STRUCTURE OF THE NEW EMS TOOL OF THE PROJECT

In this part of the report, new advances regarding generic structure and technical information of the new set of distributed EMS tools from different partners are presented. The main goal of each of these EMS tools is to achieve a seamless integration of distributed energy storage resources, working all together as a virtual and hybrid energy storage system, working as agile, flexible, and singularly as a conventional energy storage system with extended capabilities. This new generation of energy management systems (EMS) will comprise platforms that individually control EV Batteries, Home Batteries, Industrial batteries, UCAPS, as well as with the flexibility aggregation platform. The envisioned hybrid and distributed energy management systems that comprises the InterSTORE project, will have an agnostic energy storage approach, allowing the integration and the seamless operation of several distributed energy storage systems, with different power and energy capabilities, as a virtual energy storage system with extended capabilities in terms of flexibility services provision.

3.1 Generic structure in CyberNoc

The CyberNoc technology allows by design the integration of different types of flexibilities within the same hybridized portfolio. The most common use case until now was the combination of C&I demand response with distributed generation like CHP, diesel-gen sets and RES. The recent increase of BESS installations makes an opportunity for integrating them with other flexibilities, thus enabling more optimal combinations of complementary flexibilities with better market utilisation, efficiency, and monetisation. In the InterSTORE project a new generation of CyberNoc will be developed, enhanced with developed interoperability toolkit, option for integrating BESS, its hybridization, Market Arbitrage tool, Energy Community software tools and Open data space connection.

3.1.1 Interoperability toolkit

Interoperability enhancement of CyberNoc will be aligned with T1.3 specifications and WP2 Open-Source Interoperability Toolkit. With full support for up-to-date best practices in communication protocols CyberGrid holds an edge over other competitors on the market. Protocol IEEE2030.5 over NATS was recognised as such and will therefore be implemented in the CyberNoc. Regarding the implementation procedure it was decided that in CyberNoc protocol IEEE2030.5 over NATS will be implemented directly (as client/server interface). The scheme of implementation can be found in Figure 17.

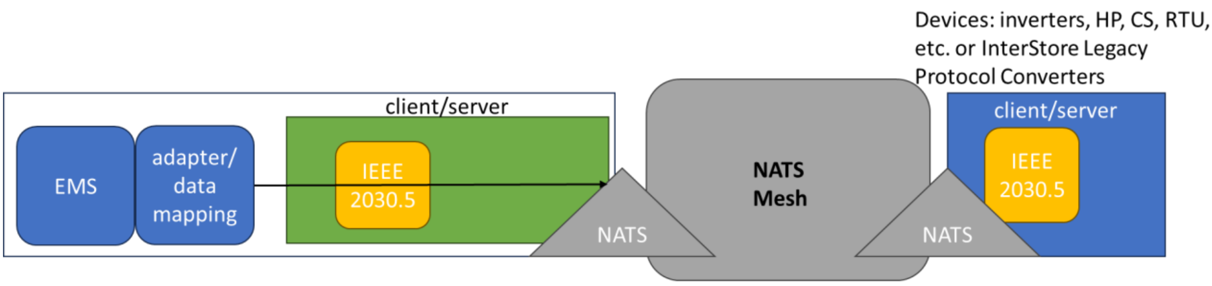

Figure 17. Implementation of IEEE 2030.5 over NATS in CyberNoc.

In addition, CyberGrid will suggest instalment of developed Legacy protocol converter for IEEE2030.5 over NATS on asset's side, to utilise all the benefits of the new protocol.

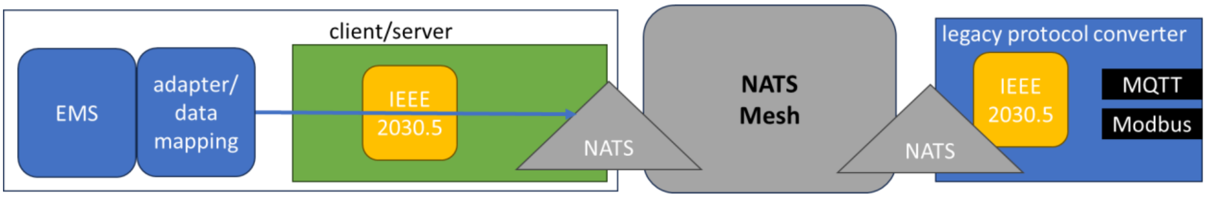

Figure 18. Legacy protocol converter implementation on assets side.

3.1.2 Hybridization toolkit

Development and integration of new BESS software toolkit will enhance CyberNoc capabilities of pairing BESS and various other flexibility assets (heat pumps, loads, RES, EVs, etc.). Features that will be added or enhanced because of the hybridization tool are as follows:

1. State of Charge (SoC) management. Monitoring SoC, portfolio flexibility and external energy prices (e.g. SIDC intraday market) the optimization algorithm selects the economically most efficient way of achieving targeted SoC.
2. Ramp optimization (management). Flexibilities can be either engaged instantaneously or ramped up/down. Ramping often proves to be more economical, however it requires proper characterization of flexibilities, their monitoring and forecasting and novel optimization algorithms.
3. Deviation fighter. Each delivery of flexibility service needs to comply with specific market product requirements which normally allow for only narrow tolerance band. RES and C&I DR flexibilities have difficulties following this requirement resulting in penalty costs and loss of revenue. With BESS added into the portfolio, coupled with its novel algorithm called "Deviation Fighter" unreliable low-cost flexibilities are upgraded to first class service.

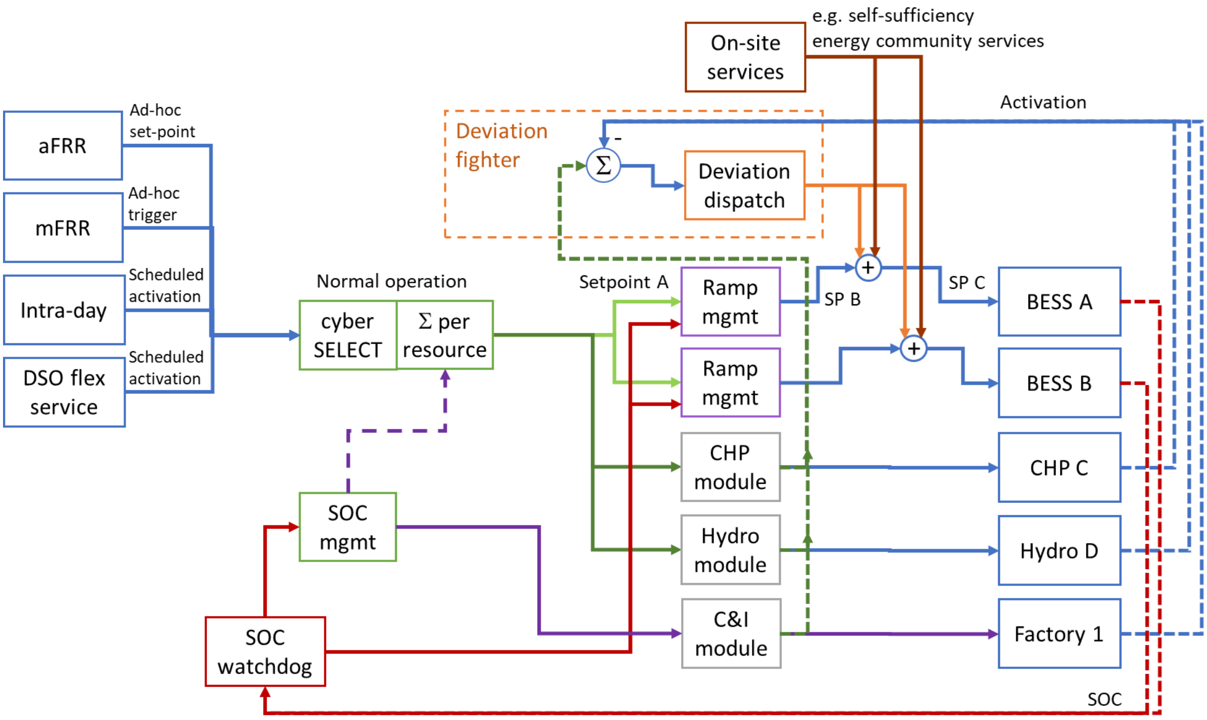

Figure 19. Conceptual diagram showing flexibility hybridization and BESS functionalities.

3.1.3 Market Arbitrage tool

Market Arbitrage tool will use forecasts of market prices and flexibility of DER to perform an optimization of the expected profit for the operator of the aggregation platform. In order to deal with the significant forecasting errors in some markets, the forecasting error distribution is considered in the bid price optimization. The tool which will be developed consists of four main steps, which are processed for each selected market:

1. Optimal allocation of market products, which results in the proposal at which product durations the flexibility should be traded to achieve the highest revenues.
2. Reservation of the required backup in the pool.
3. Calculation of the marginal costs of flexibility provision in each product period.
4. Optimization of the bid price under consideration of the marginal costs, the forecasted market price and its error distribution, and the probability of bid acceptance.

As a result, the proposed bids and expected revenues are given for each market. In the next step, the expected revenues per day are compared between the markets, and the market with the highest revenue expectation is selected. The bids for this market are the only revenues considered by the bid optimization module.

3.1.4 Energy Community software tools

Austrian residential pilot will comprise two energy communities with total of around 20-30 households. The general idea of an Energy Community is to form an additional optimization layer between the utility and the homeowner, to utilize community self-consumption and available flexibility potential.

There are three different kinds of Energy Communities in Austria:
- "Community generation plants" as defined in §16a ElWOG
- "Citizen Energy Communities" as defined in §16b ElWOG
- "Renewable Energy Communities" as defined in §16c ElWOG

The first optimization layer normally tries to use the energy within the home optimally, which is to increase self-consumption, by controlling home devices dependent on the production and consumption on site. To achieve the optimal usage of electricity inside homes different Home Energy Management systems might be used, however their installation and parametrization is not part of this pilot. However, as part of the InterSTORE pilot we will implement three possible ways of controlling the storage assets (BESS and heat pumps), generation and consumptions inside each household. The possible paths are:
- Legacy Protocol Converter (e.g. IoTmaxx)
- OEM-Platforms like the Control-API provided by Fronius
- Direct integration of IEEE2030.5/NATS devices

When optimization inside the homes is established, we can focus on optimizing the remaining energy on the level of community. This is to be done by connecting the homes to CyberNoc platform. The novel Energy Community management functionalities inside CyberNoc will comprise the latest regulatory and business/community rules (like energy accounting, static and dynamic distribution key specification, and utilization, reporting etc.) and pooling/activation optimization of available flexibility resources for various operational modes (self-sufficient community, grid balancing, wholesale market, etc.).

On the level of regulatory and business/community rules, the accounting process is of the key importance. The accounting tool is going to process all the relevant data that needs to be processed for billing purposes, but also needs to aid in managing the Energy Communities by automating the process when new members join or leave the Energy Community or when the ownership structure of generation and storage assets changes.

For the billing process the Energy Community in Austria must send regular information about assets to DSO(s). Send information must have a metadata prefix containing information about:

- Who is the supplier of energy?
- In which DSO(s) area we are operating?
- What Energy Community is it part of?
- What Generators are present?

Additionally, error detection must be organized on each of metering points so that incorrect or incomplete data can be recognized. The calculation of energy flow within these types of communities is then done by the DSO, or a joint body of DSOs in case multiple DSO-regions are involved. As DSO's calculated energy flows can be incorrect, the internal energy flow calculation automatization must be established and in case of discrepancies a notice must be sent to the DSO(s).

Regardless, the DSO's information about energy flow is then passed on to an energy-data-exchange platform - EDA. EDA process the data and sends it to all relevant players in Austria, including energy community or authorized service providers to these energy communities. From the received EDA data billing for each Energy Community member will be calculated. However, billing process will not be done directly by the CyberNoc but rather by E.GON. E.GON is an Energy Community management online platform developed by "Energie Zukunft Niederösterreich" or EZN (daughter company of EVN, specialized in Energy Community Management). To make the process of billing smooth and easy for members of the community an interface will be developed, which will allow us to access E.GON and its billing tools through CyberNoc directly.

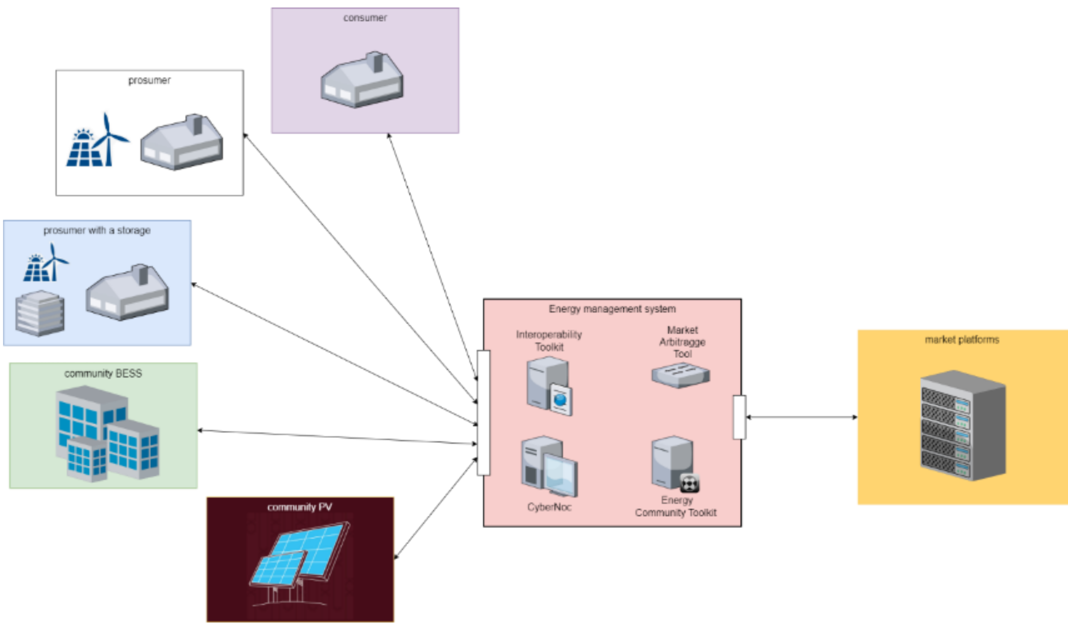

Figure 20 Schematic view of Energy community.

The goal is to provide a fully automated platform that imports all the required Data from EDA, checks the date for errors, deals with the process of changing the structure of an energy community, notifies EZN if some of these processes were not performed correctly.

3.1.5 Open data space connection

Support for Open Data Spaces aligned with T2.4 specifications. CyberNoc will be connected to Open Data Spaces with possibility to publish available DSO flexibility service (bid) and receive its acceptance information.

3.1.6 List of variables in CyberNoc

CyberNoc has a comprehensive and practical system of connecting to different DER. In order to be as simple to use a list of requested variables is short and divided between monitoring and controlling variable.

3.1.6.1 Monitoring variables

Monitoring variables are the ones originating from each DER and are collected through various ways by CyberNoc system. Their purpose is mainly to inform CyberNoc about the flexibility status of different DER.

Table 1: List of main monitoring variables-CyberNoc

Variable name	Unit	Description
Active power	kW	The active power measurement at connection to internal grid
State of Charge (for DES only)	[%]	Percentage of full DES capacity available for usage
Availability positive	Boolean: 1 = available for positive activation 0 = not available for positive activation	Indicator whether the DER is available for aggregation as an energy provider
Availability negative	Boolean: 1 = available for negative activation 0 = not available for negative activation	Indicator whether the DER is available for aggregation as an energy consumer
Activation acknowledgement	Boolean: 1 = activation started / will start 0 = activation ended / will end	Indicator whether the has received an activation command

3.1.6.2 Controlling variables

Controlling variables are send by CyberNoc to specific DER and have purpose of controlling the activation, organising the working of energy resources and dispatchment of energy in accordance with the flexibility dispatchment schedule.

Table 2: List of main controlling variables-CyberNoc

Variable name	Unit	Description
Setpoint	kW	Absolute or relative value of production or consumption of energy which DER should reach; if this value is not implemented, then it is assumed that only ON/OFF operation is available to DER.
Activation command	Boolean: 1 = start activation (and follow to the setpoint) 0 = end activation, stay in normal operation	CyberNoc sends a command to manage the operation of each DER according to its schedule
Available flexibility - positive	kW	Upper limit of the controllable flexibility bandwidth (used for positive activation); absolute or relative value supported
Available flexibility - negative	kW	Lower limit of the controllable flexibility bandwidth (used for negative activations); absolute or relative value supported

3.2 Generic structure in HyDEMS

With HESStec, the envisioned HyDEMS, should be able to reach TRL7 or TRL8 after the project, goes beyond of the current state of the art, adopting the following innovation pillars:

- Advanced assets models. The implementation of semi-empirical behavioural and degradation models of energy storage devices, provide real-time information about the available performance of the DES and how it is degraded due to the operation.
- Hybridization algorithms, operating each DES within its comfort region to leverage the maximum synergies between energy storage technologies.
- State of Function (SoF), as a virtualization layer for the grid operation based on a dimensionless vector that shows, on a very compact way, the availability of DES to perform different simultaneous services.
- Optimal multi-service operation, based on functional KPIs in multiple scenarios and considering multiple constrains in the DES pool.

3.2.1 HyDEMS concept

The hybrid distributed energy management system (HyDEMS) is a software-based control platform with a very fast communication and cloud computing capabilities, conceive to seamlessly integrate and optimize energy resources in a distributed scenario. HyDEMS will comprise a set of proprietary hybridization, degradation, and virtualization algorithms, oriented towards an optimal planning and interoperable distributed energy storage (DES) operation with the final purpose of enabling the provision of a stacked pool of multiple flexibility services to grid operators.

In fact, this product will be the Energy Management System (EMS) or Power Plant Controller of HESStec, that can be configured for different applications, from off-grid microgrids to grid-connected applications with external communications with the SCADA of DSO/TSO or connection to energy market platforms enabling the possibility of providing different services to the grid. The developed approach is based on the decoupling of power and energy technologies and satisfying needs for fast response and slow services with the combination of different storage technologies with characteristics that adjust to the needs of each specific scenario, avoiding oversizing, and excessive degradation by using technology outside of its control area.

At hardware/firmware level of the HESStec product, Real-Time Control and Communications System hosts the dedicated real-time execution algorithms (fast dynamics, hybridization, etc.), including the virtualization given by the SoF, which provides the system with the appropriate interfaces for a high interoperability and supply the necessary analog and digital channels for the measures and command signals required.

HyDEMS exhibits a real-time capability thanks to:

- The high processing capability hardware and the State of Function (software technique that minimizes the amount of data for providing a “grid service effective” data).
- Direct measurement of electrical magnitudes is directly performed by the InMS™ to avoid any delay due to communications with the SCADA or the BMS of each battery and to update the behavioural and degradation advanced assets models.
- Ultra high-speed and deterministic communication protocols is included in the communication architecture for achieving real-time performance.
- This real-time feature permits to cover from fast reaction power services to long term schedule energy services.

HyDEMS includes an architecture of local/cloud servers that support the operation and optimization of the system.

The server in the cloud, in connection with the project aggregators, hosts the databases and data with slower dynamics, such as daily planning and updating of Advanced Asset Models, both in behaviour and degradation, through advanced data decision-based techniques. The local server implements the advanced real-time asset software as well as the hourly operation algorithm and the correction of deviations with respect to daily planning. At this software level, the Hybridization and Management System Tool, for the real-time operation of the storage, providing multiple services is included.

Figure 21. Example of HyDEMS prototype.

The hybrid approach, the integration of degradation and operation models of energy storage and the virtualization feature of the HyDEMS permits to cover a wide range of scenarios and applications; configure multiple optimization targets for different flexibility services for the distributed energy assets. The envisioned HyDEMS, will reach TRL8 after the project, goes beyond of the current state of the art, adopting the following innovation pillars:

- Advance monitoring system: It can monitor in real time the SOC and SOH indicating the available performance of the technology and how it is degraded due to the operation depending on the service/s to be delivered.
- Hybridization algorithms: operating each DES within its comfort region to leverage the maximum synergies between energy storage technologies.
- State of Function (SoF): as a virtualization layer for the grid operation based on a dimensionless vector that shows, on a very compact way, the availability of DES to perform different simultaneous services.
- Optimal multi-service operation: with advanced capability of providing wide range of services, very fast to very long-term services, based on functional KPIs in multiple scenarios and considering multiple constrains in the DES pool.

A generic application of HyDEMS is presented in Figure 22 which is showing hierarchy used for HyDEMS on different nods. The DEMS/HyDEMS use a standardized payload communication to share the minimal information as SOC, SOH, SoF (capabilities of the DEMS) with the aggregator. The aggregator uses this information to implement the interoperability of flexible services. For example, the Node 1 could be consisted of multiple DER as battery (DER1), ultracapacitors or HEMS for (DER2) with a relative SoC, SoH, SoF, etc.

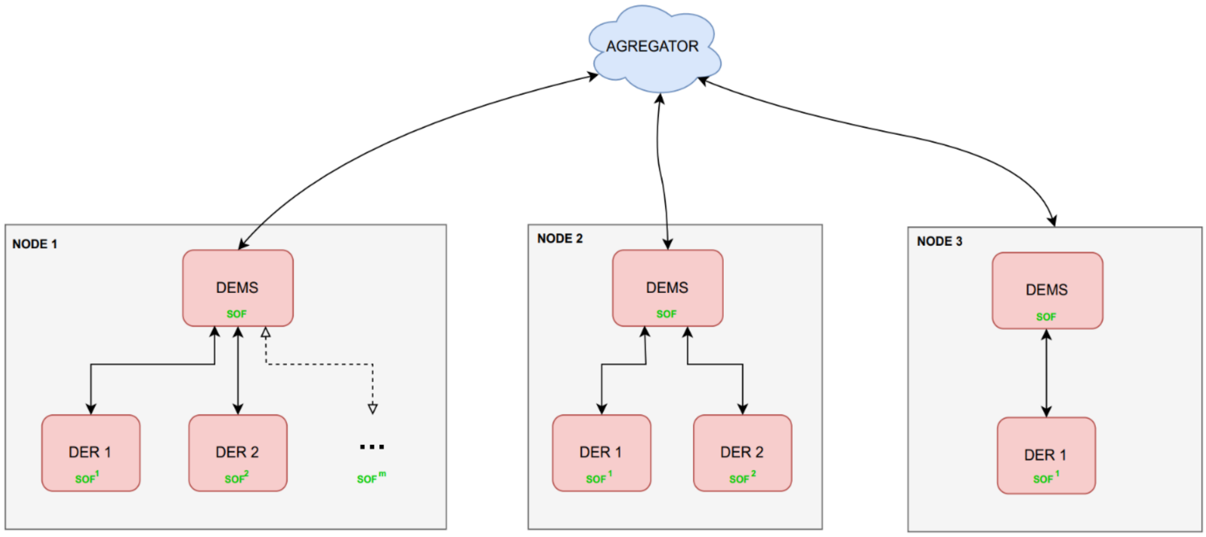

Figure 22. Schematic example of HyDEMS in the context of the project.

As shown in Figure 22, on top of each DER a DEMS unit can be incorporated which can communicate between aggregator and each of the DER for providing possible interoperable smooth response of the system. According to this application of HyDEMS, the distributed energy management platform must virtualize the HESS, and establish a channel with the aggregator to exchange data of the capability/availability of the DER to provide a specific pool of flexibility services (State of Function, SoF). Therefore, a common language, defined a SoF, will be used for each DER, as one of the main features of the new generation of energy management system which can smoothly enables the hybridization of different DER in the system. This innovative virtualization approach impacts at the interoperability with the system operator, providing tools that will contribute to mitigate barriers related to lack of knowledge and complexity of new storage assets into the grid.

3.2.2 State of Function definition and application to HyDEMS

It's important to understand that distributed and hybrid energy storage resources are becoming increasingly common in modern grid systems. These resources include UCAPS, Home batteries, EV stations, and other technologies that can store energy for later use. However, the variety of technologies and manufacturers can make it difficult to compare and evaluate the performance of different energy storage systems. That's where SoF comes in as advanced interoperability tool. SoF provides a standardized approach to describing and evaluating the performance of energy storage systems, regardless of the technology or manufacturer. SoF breaks down energy storage systems into their functional components, such as power conversion, energy storage, and control systems, and provides a common language for describing their capabilities.

The figure of merit called State of Function (SoF) has been conceived for the implementation of the virtualization, in order to simplify the optimization process and the interoperability with end-user, external systems and energy or power management systems (EMS or PMS). SoF is based on a dimensionless vector that provides a measure of the flexibility potential, indicating the real-time capability of an energy storage system to provide different and simultaneous services (and at what extent) at any moment depending on the state of the system and past operation, avoiding the exchange of a high amount of technical data to be post-processed by the user for obtaining an interpretation.

This figure of merit translates the parameters from the “base technology language” (SoC, SoH, etc) to the “system operator language” (variety of services and responses to be provided). The hybrid approach taken in the foreseen EMS/PMS and the use of the SoF are the two key issues for the virtualization of energy storage solutions with an extended performance, instead of operating the storage solution as a simple aggregation of blocks and storage devices. This innovative virtualization approach, represented in Figure 23. , impacts at the interoperability with the system operator, providing tools that will contribute to mitigate barriers related to lack of knowledge and complexity of new assets into the distribution grid.

In general, virtualization provided by SoF permits a high interoperability not only with an external system operator, but also between all the elements controlled in the (micro)grid, facilitating the implementation of hierarchical control layers and distributed control strategies.

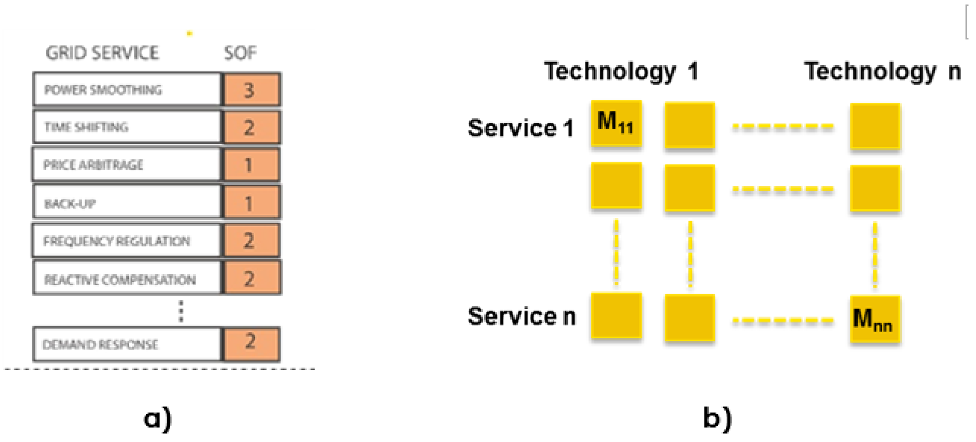

Figure 23. Illustration of SoF: a) SoF for one technology; b) SoF for a set of technologies

This standardized approach enables more effective comparison and selection of energy storage solutions, which can improve the coordination and management of distributed energy resources with efficient interoperability. For example, if a utility needs to integrate multiple energy storage systems into their grid, they can use SoF to evaluate the capabilities of each system and select the ones that best meet their needs. This can help to optimize the use of energy storage resources and improve the overall performance of the grid.

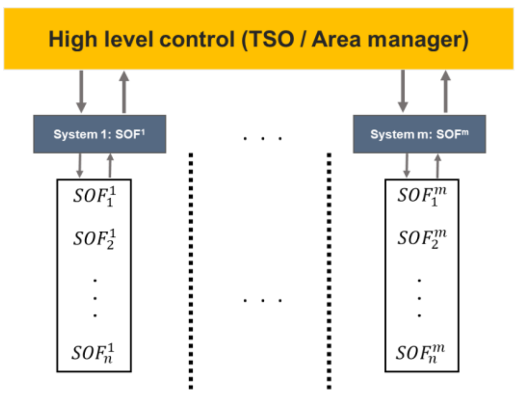

Figure 24. Incorporation of SOF for each component.

Therefore, according to the system state, a hybridization algorithm will be implemented to use different type technology within each of DERs for providing different services. For each service, the received profile reference signal by DEMS will be categorized, by hybridization algorithm, from very fast to very slow corresponding to each DER.

In the new generation of energy management system, a more advanced tools so called SoF will be incorporated for all different DERs to prioritize the different available distributed energy storage (DES) technology according to their current state for providing each specific service. In this case, the SoF will be incorporated in all hybridization level. This would be interesting when in some application several similar storage technologies at different locations (distributed scenario) are available and the use of SoF will be crucial for prioritization of the use of each DER components on its most optimum way. The main goal of having SoF is to obtain, in a simple way, the capability/availability of each DER to provide a determined grid service.

The SoF can be used to monitor and optimize the operation of the hybrid energy storage system. By measuring and analysing different measures indicating the real time state of the system, the SoF can be used to make decisions on how to allocate and balance the load/service between the different DERs. The SoF can be calculated based on various parameters, such as the state of the energy, state of charge (SoC), state of health (SoH), and other relevant system variables which can be as follows:

- Real time state of energy of each DES components
- The SoC refers to the amount of energy stored in the storage system relative to its maximum capacity.
- The maximum available power that the storage component is able to inject in the grid.
- The maximum available power that the storage component is able to absorb from the grid.
- The maximum time that the DES component can inject in the grid its maximum available power to inject.
- The maximum time that the DES component can absorb from the grid its maximum available power to absorb.
- The SoH, on the other hand, refers to the health of the storage system, such as the degradation of the battery or the wear and tear of the mechanical components.

By monitoring some important values such as energy state, SoC, … mentioned above, the SoF can make provide a unique language about the state of each DER which can be used on allocating the requested services between the different DERS, such as Home batteries, capacitors, and EV stations.

Implementing a State of Function (SoF) monitoring system for a HESS system can involve several steps:

1. Identify the relevant system variables: Determine the key parameters that need to be monitored and analyzed to calculate the SoF. This can include variables such as energy of each DES component, the state of charge (SoC), state of health (SoH), temperature, voltage, current, maximum/minimum allowed power, inject/absorb condition modes for each of the storage components.
2. Develop a monitoring system: Install sensors and data acquisition systems to monitor the relevant system variables in real-time. The sensors can be wired or wireless, depending on the specific application. The data acquisition system can be a dedicated system or a software-based solution that collects data from the sensors and processes it.

3. Develop a SoF calculation algorithm: Develop an algorithm that calculates the SoF based on the monitored system variables. The algorithm can be simple or complex, depending on the specific application. The algorithm should consider the performance characteristics of each storage component and be able to make decisions on how to allocate and balance the service/load between the different DERs. The SoF algorithm defines the different modes of operation for the hybrid energy storage system based on the SoC and temperature of each storage technology.
4. Integrate the SoF monitoring system with the hybrid energy storage system: Integrate the monitoring system with the control system of the hybrid energy storage system so that the SoF can be used to make real-time decisions on the operation of the system.
5. Test and validate the system: Test the SoF monitoring system in real-world conditions and validate its performance. This can involve testing the system under different operating conditions and comparing the results to expected performance metrics.

As shown in Figure 24, In a low hierarchy control layer, each storage technology or asset has its own SoF. Following a hierarchical or distributed approach, the EMS/PMS creates a sole SoF of the hybrid storage solution or a microgrid. Different appcoaches can be used for adapting the SoF to the real system application:

- Hierarchical or vertical approach: Simplify the processing and facilitating the operation by higher control layers, decoupling low level issues from the top-level operations, allowing a lighter implementation of real-time and optimisation algorithms. This hierarchical approach allows having multiple levels of virtualization. In case of non-autonomous approach, EMS/PMS guides end-users in case of external operation, indicating the possible services (and combination of them) to be provided.
- Distributed or horizontal approach: In the case of coordinated operations with other control or energy management devices of other systems, the SoF is the base of the exchange of information, facilitating the coordination and integration of distributed storage systems with multiple technologies, energy vectors and loads as a single entity such as a Virtual Storage Plants.

In an interoperable energy storage project, the SoF needs to ensure that the different DES, DER technologies can work together seamlessly, without causing any compatibility issues or system failures. This may involve developing protocols for communication and control and ensuring that the different technologies can be connected and managed in a way that maximizes their performance. For example, the SoF may need to define how the different DES, DER can be charged and discharged in a coordinated way, without causing overloading or undercharging of any individual DES technology.

Overall, the implementation of State of the Function involves developing a standardized methodology, establishing a database, conducting SoF assessments, populating the database, and using the data to inform decision-making and identify areas for improvement. By providing a common language for describing and evaluating the performance of energy storage systems, SoF can help to improve the interoperability of distributed and hybrid energy storage resources and accelerate the transition to a more sustainable energy system.

3.2.3 List of variable and technical requirement of HyDEMS

In this part, a tentative list of potential variables suitable to determine indicators or variable which will be used for providing services is provided. HESStec has a comprehensive EMS system with capability of providing different services on different applications. The technical data of the tool with list of main useful variables are presented in Table 3 to Table 6.

Table 3: Technical data of the EMS tool of HESStec

TECHNICAL DATASHEET (MPV)		
DUAL CORE PROCESSORS	ARM	NXP i.MX6 Quad ARM Cortex A9
		1.0 GHz L2 cache 1MB
		2 GByte onboard DDR3 memory
		Linux emmbebed
	DSP	TMS320C28346 Delfino Microcontroller
		32-Bit CPUs 300MHz
		On Chip Memory 516K RAM
		On Chip Memory 258K × 16 SARAM
		IEEE 754 Single-Precision Floating-Point Unit (FPU)
		300 MIPS
		Real Time Clock with battery backup
		Watch dog Timer
COMMUNICATIONS PORTS	ARM	ETHERNET
		CAN BUS
	DSP	CAN
DATA STORAGE		SD Card
IO PORTS		16 channels analog input ±5V range up to 16bits/ 140kh max sample rate
		4 channels analog 10k NTC input 12bits
		4 isolated digital input
		8 relay output

Table 4: Main expected variables to identify the HESS management system characteristics and operation.

Name / Description	Unit
BESS Status (Shut-down / Starting-up / Standby / Operating / Failure)	Various
SOC	%
SOH	%
Available Energy	kWh
Maximum energy	kWh
Available charge/discharge current	A
Available cycles of charge/discharge	-
Energy/power ratio	Wh/W
ESR	Ohm
Temperature range (working)	°C
Temperature range (shelf)	°C
Start-up time	s.

Shut-down time	s.
Restart time	s.
Efficiency indicators evolution (ageing behavior)	%/year
Available power (taking into account control system, SSAA consumption, and current limit and voltage of Battery/Ucap, and maximum power at POC)	kW
The maximum time that the storage component can inject/absorb in the grid on its maximum available power to inject/absorb.	s.
Efficiency indicators (e.g. one way efficiency, round trip efficiency, charge/discharge energy efficiency, charge/discharge faradic efficiency)	%
Control system dynamics (response time, intervention time in case of alerts)	s.
Standard solicitation profiles for power/energy application (Voltage, current, SOC, Temperature, SOH)	Enumeration

For supporting the necessary actions to achieve the matching between available information and protocols and expected specifications, an initial list of required information and the current available ones have been collected. They are respectively summarized in generic way in Table 5 and Table 6.

Table 5: tentative list of required information for hybrid system sub-systems integration.

Name / Description
Block diagram connection scheme of the developed system
Model of the battery (storage components)
Component ratings (battery, inverter, filter)
Feedback signals for the controller
Number of converters in full system

Table 6: currently available communication protocol for the HESS development.

Currently available typical or suggested devices (within partner development/production)	
Communication interfaces (types and sizes)	TH: Modbus (TCP, SunSpec); IEC 61850 (MMS Server, GOOSE, SV); IEC C37.118; Ethernet Variable Exchange; CANBus; CANOpen; DNP3

As a complementary part of this section list of some important variables for SoF off-line and real time application cases can be presented here.

The definition of the SoF is intrinsically related to the services to be provided by the energy storage system. In order to evaluate the SoF, the EMS must receive, via communications or signal acquisition, certain electrical parameters that enable the EMS to configure the dimensional vector that represents the capability of the energy storage system to provide a specific grid service.

As shown in Figure 25. and Figure 26. , the SoF value per service is based in two analyses for offline and real time schemes. One offline analysis that creates the SoF model depending on each service and each energy storage technology. Every energy storage system is tested under each service power profile, and through the harvesting of the physical variables of the energy storage (Voltage, Current and Temperature) at different levels (Cell, Module and System) and based on the manufacturer initial values for each storage (ESR & Capacity) a semi-empirical SoF* vector (composed by SoF^{*}_{n}) is calculated.

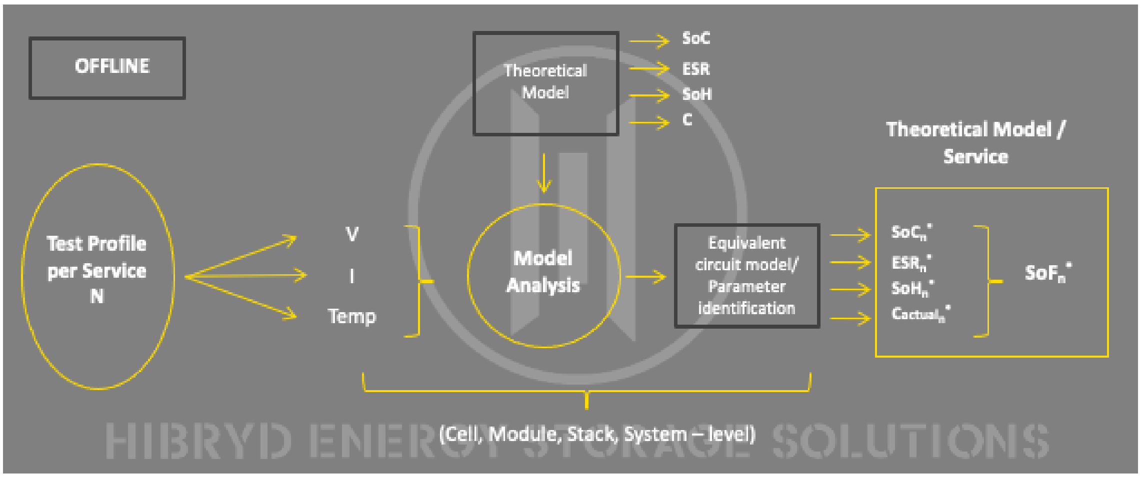

Figure 25. Offline analysis that creates the SoF model

During the real time operation and through the physical variables harvested on that operation and the storage's values calculated, a dynamic SoF is evaluated, this vector is used for the real time operation and to improve the offline SoF calculated in the lab.

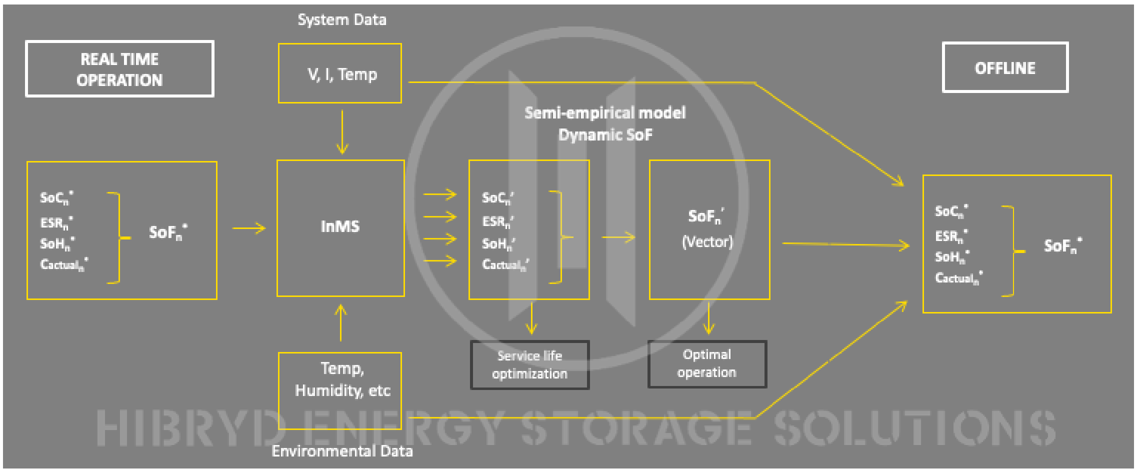

Figure 26. Real time scheme for SoF evaluation

3.3 Generic structure of the HEMS

Going beyond the state of the art, new trends in the market are acknowledged caused by normal technological maturity. First, the growth in non-intrusive load monitoring (NILM) techniques is now making it possible to collect energy consumption data down to the level of appliances. The disaggregated energy data thus collected is more meaningful to the consumers. Second, due to the pervasive availability of sensors, it has become easier to collect different dimensions of data, including ambient temperature, humidity, and lighting, that can be integrated by energy management systems to provide more contextual information and thus increase their effectiveness. Third, cloud computing and mobile platforms have made it possible to perform large-scale analytics on sensor data and offer advanced real-time feedback to the consumers. Finally, the growing popularity of social networks, has made it easier to incorporate comparative and persuasive features into energy management systems to motivate behavioural changes in consumers. For these reasons associated with new assets becoming available to households, is most likely that EMS will evolve to much more comprehensive tools.

3.3.1 HEMS new features concept

Moving beyond the state of the art, in InterSTORE, InescTec will add to the current system, hybrid storage systems managing capabilities, monitoring and analysis. The system as modular as it is, foresees a dedicated Webapp to show case the new features. Since no households participate in the Portuguese Demo, the HEMS connect app will not serve any purpose, since in this case the consumer is an industrial partner (CapWatt). To this end, the load optimization, dispatch scheduling of the batteries and monitoring metrics will be shared via REST API communication and web application. For communicating information for DR purposes to the EV users in UC6, CapWatt will communicate internally to their workers (participating EV users) the corresponding information with time and incentive table.

The HEMS back end new feature will focus on the HESS for hybridization of the two battery systems that we have in the location. A vanadium battery with 10kW and 40kWh by VisBlue manufacturer and a 2nd life lithium phosphate battery of 100kW and 100kWh capacity with the inverter by IngeTeam model IngeCon Sunplay 3 10TL. Both systems will be connected to a computer that hosts the BMS running in LabView. The backend new developments will be python-based and will incorporate the following features:

1. Database created using PostgreSQL
2. The application will perform a forecast of the consumption of the associated loads
3. It will perform the flexibility estimation receiving as inputs explicit demand response needs with a JSON format using a REST API. It will also receive implicit demand response signals such as tariffs (or in our case an environmental signal in CO2/kWh) from an external platform called Sentinel also using an API get request.
4. It will perform the load optimization and provide a dispatch report for operating the HESS
5. It will send a daily signal, an array with 24 values with the implicit DR signal to the EV users' smart phones.
6. The Database used for the HEMS new features will be deployed in the same machine as the (OneNet connector enabling the communication with the connected data spaces in InterSTORE.

7. It will perform the comparison between the baseline (forecast) and the actual consumption to determine the actual provision of the demand response/flexibility requests.

Making reference to Figure X showing the microservices domain, the new service to be added will be the HESS optimal scheduling, as an independent module as shown in Figure 27.

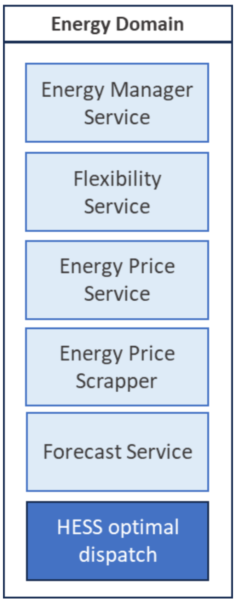

Figure 27. Inclusion of new Microservice in the Energy Domain.

3.3.2 HEMS new features architecture

Figure 28 shows the architecture of the new microservice in terms of tools and interactions between systems and third-party platforms.

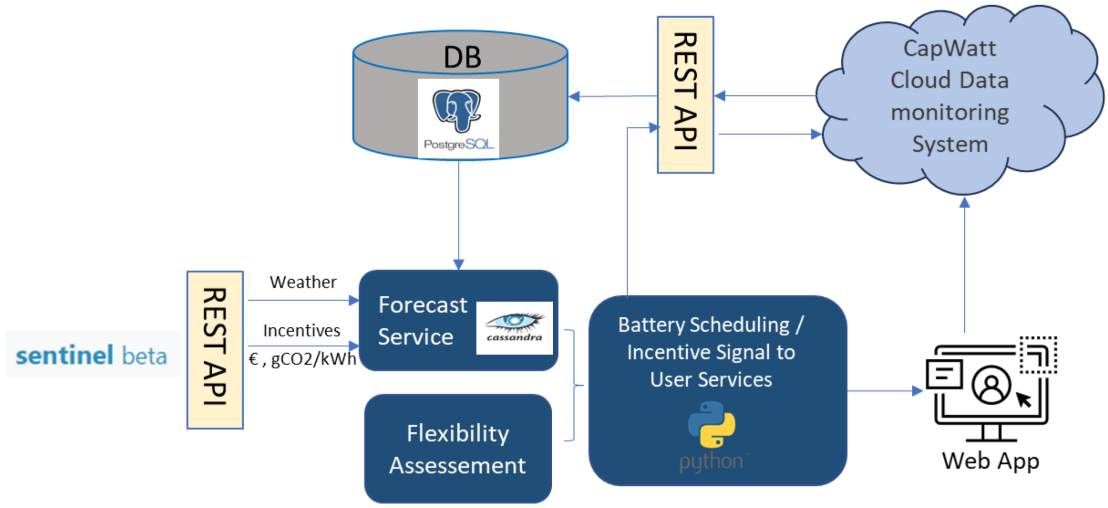

Figure 28. General Architecture of the battery scheduling service

The service will retrieve information about the load diagrams of the loads from CapWatt to perform a forecast which is stored in a PostgreSQL database. This is possible by training a machine learning model with the historical data and weather forecast for that specific location, using the Cassandra environment in the HEMS. With the forecast of the load and the incentives for the next day, obtained from the sentinel platform in €/kWh or gCO2/kWh, it will be possible to schedule the batteries to achieve the lowest cost (or environmental impact) of supplying energy to the building. The model takes into account the degradation curves of the batteries in case it is a Hybrid system and minimizes the degradation. This is ensured by including the degradation weight in a linear optimization function, adding to the energy cost of supplying energy to the load/building. The optimization problem is run in python scripts and a web application will be available for testing different scenarios and configurations.

In summary its main functions are monitoring and data analytics on energy usage; optimal scheduling of flexible assets to provide demand side flexibility support. In terms of variables and Time steps, the system functions are mainly energy and power from several flexible assets (in this case batteries), as well as load profiles for optimization and decision support in configurable time horizons (e.g. 15 min or lower).

3.3.3 List of variables:

In this section, a tentative list of potential variables suitable to determine indicators or variable which will be used for providing services needs to be provided.

InescTec has a comprehensive and practical system of connecting to different appliances. In order to be a simple one to use, a list of variables is divided between monitoring and controlling variables.

3.3.4 Monitoring variables

Monitoring variables are the ones originating from assets and external platforms and are collected through various ways by the HEMS micro-services. In the developed new features being applied to UC5 and UC6, a collection of variables with different time steps and reporting periods exist. Their purpose is to provide inputs for the algorithms running as micro-services in the HEMS architecture, such as processing, to train models, to inform about current status, comparison to baselines, forecast attributes, flexibility estimation, etc.

Table 7: List of the main monitoring variables-HEMS tool.

Name of variable	Unit	Description
Load Diagram	KW and time (time series, hourly or 15 min time step)	For load forecast and flexibility estimation
Weather forecast for location	Temperature °C	For load forecast
Environmental incentive signal for DR	gCO2/kWh	From Sentinel platform API, used for demand response signal
Price incentive signal for DR	€/kWh	From ENTSO-E platform API, used for demand response signal
State of Charge of batteries	[%]	State of Energy of the battery as percentage of total capacity
State of Charge of Batteries	kWh	Absolute energy value in kWh of energy stored

Operating Active Power (Negative or Positive)	kW	Active Power observed when charging and discharging
Operating Reactive Power	kVAr	Reactive Power observed when charging and discharging
AC Voltages	V	Operating voltage on the AC side (after the inverter)
Phase Currents	A	Three phase current observed under operation
Battery Temperature	°C	Temperature coming from the battery sensor
Frequency	Hz	Frequency of operation
Limit Power of the parking Lot	kW	Contracted Power/Power limit of the infrastructure
Aggregated Power of the Parking Lot	kW	The aggregated power of the parking lot from EV charging plus the supporting battery operation cannot be higher than the infrastructure limit.
EV charging session info	Charging in KW and time of session (lowest time step possible)	Information about charging session from EV user card ID
Actual daily operation scheduling of the batteries	Daily time Power in kW and time (hourly/15 minute time step)	Info in order to compare with the recommended scheduling

3.3.5 Controlling variables

Controlling variables are send by the HEMS as dispatch or load optimization schedulling, not as a direct control command of the units. The following variables are shared with the industrial site (Capwatt) cloud data and monitoring system:

Table 8: List of the main control variables-HEMS tool.

Name of variable	Unit	Description
Battery Active Power Setpoint	kW	Provides the battery a set point to charge discharge acording to the schedule
Battery Scheduling	KW and time (day ahead time series)	Schedule of the battery for the next day operation in active power
Reactive Power Setpoint	kVAr	Optional schedule of the battery for the next day operation in reactive power
Environmental incentive signal for DR	gCO2/kWh	From Sentinel platform API, used for demand response signal for the battery optimization and EV user DR
Activate battery	Boolean 0 Off 1 n	Turn on or off support battery for EVs

3.4 Hybrid Asset Management and Flexibility Architecture in ENX

As it explained in Section 3.4, within the InterSTORE scope, Enel X will add to the current systems: hybrid storage system managing capabilities, monitoring, and controlling. As described in section 2.4, there are two domains of development: development for the VPP Manager software and development for the Asset Manager software.

Regarding the Asset Management software, a key outcome of InterSTORE is the adoption of Interoperable client/Server for distributed Energy Storage. The Asset Management software is responsible for reliably responding to signals sent by the VPP Manager software, regarding opportunities for grid services. However, the Asset Management software may also be responsible for forecasting site load, accounting for weather forecasts, and any other aspects that may affect the hybrid assets.

Regarding the VPP Manager software enhancements, InterSTORE will ensure that ENX systems have the ability to signal distributed hybrid energy resources, requesting flexibility and grid services. Enel software will send commands to the assets, based on the needs of the grid. Enhancements to the VPP manager may include that ability to acquire telemetry from distributed energy resources and compute aggregated site performance. Additionally, InterSTORE will require that the VPP Manager software connects to the Asset Manager software.

In this way, ENX Platform will be able to satisfy the needs and constraints of hybrid systems, as well as better provide grid flexibility solutions.

Figure 29 shows the E2E architecture of the new microservice in terms of tools and interactions between systems and heterogeneous assets installed in Rome's Enel X "Xlab".

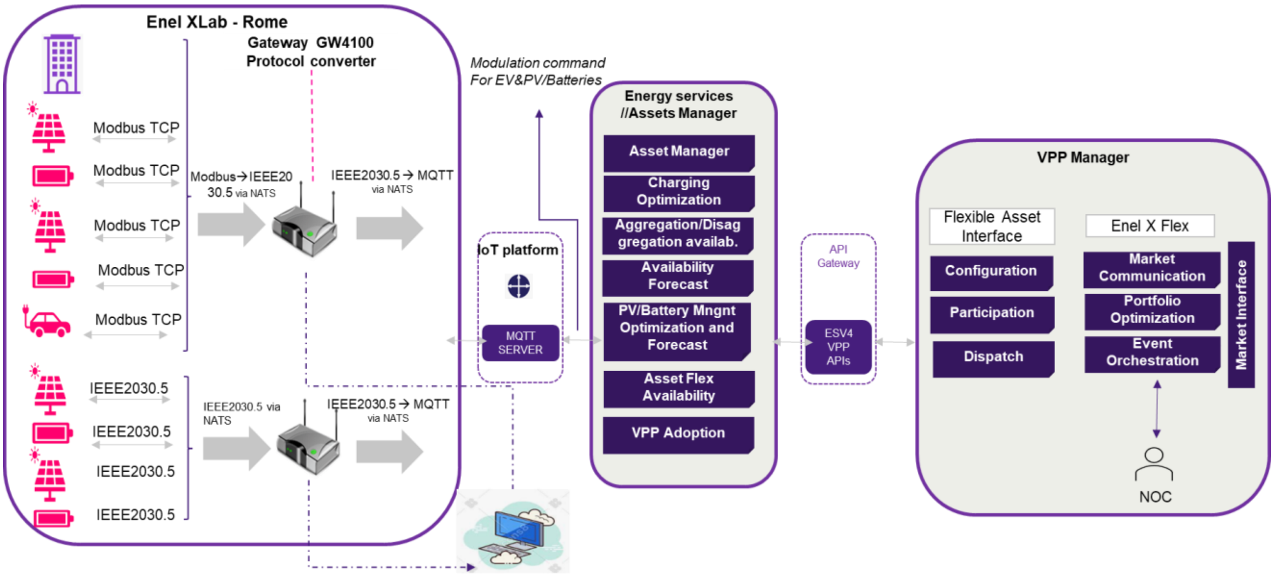

Figure 29. End to End EnelX Flexibility Infrastructure.

3.4.1 VPP Manager capabilities

The VPP Manager platform is able to manage different market products by signalling for the power of several DERs. The VPP Manager can deliver the same service and redundancy and can subsequently trade on the same energy markets as large, centralized power plants.

The main capabilities are 1) Market Communication, 2) Portfolio optimization and 3) Events Orchestration, 4) Settlement, and 5) Auditing and On-boarding.

To facilitate Event Orchestration, there is a team working 24/7/365, the Network Operation Center (NOC), and they are able to monitor and guarantee that all the requests coming from TSO are satisfied in compliance with the agreements entered.

The VPP Manager is integrated with the Asset Manager via an interface, which enables communication necessary to execute events; participation/bidding and dispatch signals are passed between these two platforms.

Order example manually configured:

When Flex receives a dispatch order from a System Operator, a dispatch event is created and the dispatch schedule/command is propagated to the assets through the Flexible Asset Interface and the Asset Manager. The Asset Manager dispatches the single assets and ensures that the amount of capacity requested by the order is delivered during the duration of the event. Flex also allows monitoring the performance at the aggregated level in real time during the event.

3.4.2 Asset Manager or Energy Services

The Asset Manager is the platform in charge of adhering to the asset-level constraints and responding reliably to dispatch signals from the VPP Manager software. The main Asset Manager capabilities are:

1) Asset Management
    a. Battery/EV management and Optimization Forecast, including Charging Optimization
    b. PV Management and Optimization Forecast
2) Reliable response to dispatch signals from the VPP Manager
    a. Availability Forecast, including the ability to estimate grid service bids
    b. Aggregation of assets to bid into a grid services
    c. Disaggregation of dispatch signals from the VPP Manager
3) Dispatch signal to single asset

Asset manager is the system which:

- receives events from VPP Manager/Flex platform. In this context a typical signal could be to reduce the power consumption of a specific site. The asset related to the signal is an aggregated asset (Virtual Flexible Asset) which is then disaggregated in physical assets by the asset manager.
- disaggregates the virtual flexible asset (VFA) in physical assets. This activity takes into account the physical assets (known only by the asset manager) which best fulfill the request received from the VPP. In this phase several algorithms may be used in order to choose the physical assets which fit best with the request
- controls the identified physical assets thanks to the integration with the IoT platform. In this phase the Asset manager modulates the physical assets in order to fulfill the VPP events received

3.4.3 IoT platform

Conceived in 2017, Enel Global IoT platform (EGIP) supports connectivity and edge-computing globally.

It is an Open, modular and secure platform which implements the following Capabilities:

- Acquire data from real world
- Manage device fleet and onboarding
- Send and receive command
- Enforce communications security
- OTA and Remote Control
- Rule Engine and device monitoring

In InterSTORE scenario, it would allow through its third party specification integration registration, monitoring and remote management of gateway protocol converters.

These devices will interact with EGIP public endpoint using mqtts protocol to send telemetry messages and receive remote commandsIoT platform would forward telemetry messages to the energy services aggregation platform and would accept commands sent from the latter one, delivering them to the converters.

It is converters ownership to translate commands into IEEE2030.5 protocol. To meet security constraint, gateway protocol converters must interact with Public Key Infrastructure, using EST protocol.

EGIP third party integration specification are subject to a non-disclouse agreement (NDA). On-boarding, management and communication with EGIP platform are described in an internal document "20230620_IoT_ThirdPartyIntegrationSpecification", released with NDA signed. Among integration model provided by EGIP, we proposte a 3rd party IoT Light Gateway, a "minimum-requirements" gateway that interacts with the platform using MQTT/TLS and executing gateway commands, by managing only one gateway certificate and acting as a proxy for all connected devices. 3rd party IoT Gateway are intended to be developed, provided and configured by the vendor/integrator as part of the systems being integrated into EGIP

In the table below there is a recap of some of the tentative feature which a 3rd party devices would implement and support during the project. Page column gives reference to the doc "20230620_IoT_ThirdPartyIntegrationSpecification".

Table 9: currently available features of the 3rd party devices.

Command/Feature	Compulsory	Page	NOTE
PKI integration	Y	208	Strongly suggested: EST mode. With a single pkp you can enroll n certificates without any challenge password (required in SCEP)
Gateway registration	Y	16	Strongly suggested: Light gateway Integration, to save certificates to enroll
Collect Logs	N*	72	it is not compulsory if device troubleshooting is managed by maker with its infrastructure
Activate thing	Y	104	Strongly suggested for commands integration: via Aws Job. Applied to all of the commands
Deactivate Gateway	Y	76	
Deactivate Thing	Y	34	

Device Remote Control	N	36	
Collect History Log	N*	68	it is not compulsory if device troubleshooting is managed by maker with its infrastructure
Monitoring activation	N	43	
Reboot	N	46	
Remote Software update	N*	48	*it is not compulsory if firmware device management and device troubleshooting are owned by maker with its infrastructure
Renewal certificate	Y	53	
Update Thing	Y	59	
Update-state	Y*	108	This is a core command used to support thing commands. You can choose to get this channel to send command to the things or create a dedicated thing commands API on Vertical app layer (e.g. Evos uses Vertical App layer)

3.4.4 Interoperability end Gateway converter

Below its showed how the asset data environment in XLAB will be built in order to be compliant with IEEE2030.5 protocol.

A gateway converter will be installed in Xlab (for the protocol converter HW we plan to use the Linux based IoTmaxx GW4100 or enhanced model) in order to have a Legacy protocol converter for IEEE 2030.5 over NATS on asset's side, to utilize all the benefits of the new protocol.

In Xlab will be available assets with IEEE2030.5 native implemented and assets in Modbus protocol for which it's requested a protocol converter in IEEE2030.5.

In addition the data in MQTT protocol will be available from the gateway converter to the IOT Platform for assets data telemetries

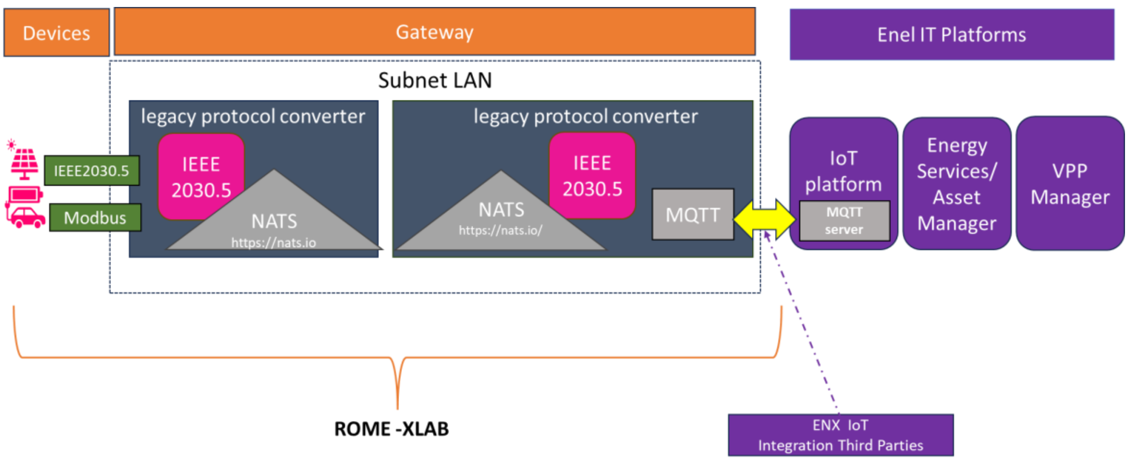

Figure 30. Asset data environment considering IEEE2030.5 protocol.

3.4.5 IEEE2030.5 Functions implemented in XLAB

With reference to the native IEEE 2030.5 devices, Schneider Electric XW Pro Hybrid inverter was selected for this trial.
The XW Pro hybrid inverter provides energy security for residential, small commercial and offgrid applications. With high power ratings and 2X surge capability, the XW Pro is reliable for backup power operation and off-grid loads. In addition, broad battery compatibility provides flexibility in system design. It can be used for solar and storage or backup power systems without solar.
Therefore, when equipped with the XW Pro, the Lab slot may be used as EESS, PV plant or EESS/PV hybrid plant, by giving the maximum level of flexibility in the use cases implementation.
The XW Pro is IEEE 2030.5 certified when connected to the gateway device and External Monitoring & Control is done by client-server communication type. This includes California Rule Phase 3 Functions 1, 2, 3 and 8:

Functions implemented in IEEE2030.5:

California Rule Phase 3	Monitoring DER DATA
Function 1	Reactive power
	Phase voltage
	Frequency
	Energy Storage state of charge (%)
	Operational State
Function2	DER Disconntected and Reconnected command
Function 3	Limit Maximum Active Power Mode
Function 8	Scheduling Power Values and Mode
	Volt- Var curve control
	Fixed power factor control
	Volt-Watt curve control

3.4.6 XLabs Asset list

There are three facilities that may be used for this pilot project.

X Lab 1 is the testing field for medium-scale solutions (e.g. medium residential, small commercial and industrial). The laboratory is composed of 2 interconnected microgrids (MGs):

- 20 kW scale DC MG at 48 VDC that can reach 300 kW if operated at 750 VDC (the nominal voltage is adjustable in the range 48 V – 750 V)
- 64 kVA scale AC MG.

The microgrid has off-grid and grid-connected capabilities.
Off-grid means that the tested solution is not connected to the main grid, and on-grid means that the tested solution is connected to the main grid. These features allow for different

testing modes, AC/DC hybrid testing, testing of any AC or DC devices, and interoperability testing.
The lab also includes two 12 kWp photovoltaic (PV) plants with innovative bifacial Enel 3SUN panels that can reach 14.5 kWp in bifacial way and two (1 AC and 1 DC) regenerative grid simulators.

X Lab 3 is the test eld for small scale solutions (e. g. small residential, very small commercial and industrial).
The laboratory is composed of 4 interconnected microgrids (MGs):

- two 9 kW scale DC MGs at 48 VDC that can reach 140 kW if operated at 750 VDC (the nominal voltage is adjustable in the range 48 V – 750 V).
- two 15 kVA scale AC MGs.

O-grid (the tested solution is not connected to the main grid) and on-grid (the tested solution is connected to the main grid) testing modes, AC/DC hybrid testing, testing of AC or DC devices, and interoperability testing are available. Any type of solution/device can be tested: power converters, EESS, e-car charging stations, etc. The lab is completed by two 3.7 kWp photovoltaic (PV) plants with innovative bifacial Enel 3SUN panels that can reach 4.5 kWp in bifacial way and four (2 AC and 2 DC) regenerative grid simulators.

X Lab 5 is the place where large-scale solutions are tested (e.g. large residential, medium commercial, and industrial).
The Lab architecture is composed by:

- 132 kVA – 274 kWh Li-Ion electrical energy storage system (EESS).
- 150 kVA – 150 kWh energy intensive supercapacitor EESS.
- 102 kWp PV plant with innovative bifacial Enel3SUN panels, that can reach 125 kWp in bifacial way.

This special architecture allows several test configurations, such as High Power Charging station (HPC) integration with energy intensive supercapacitors, large-scale solution integration (PV, EESS, e-mobility), energy flexibility management and building energy management.
Lastly, Enel X facilities may offer the ability to test EV Charger V2G. The bidirectional EV supply equipment allows a wireless connection thanks to a dedicated modem with a SIM. Moreover, an Ethernet output is available, which could operate for the connection to the external center, after parameters configuration. The connection to the aggregator platform the communication is based on OCPP 1.6.In addition to communication to the remote center, a local communication with a local controller is possible via Modbus TCP/IP communication protocol.

Finally, X Lab has Living Lab capabilities, because is part of a real building where other facilities are working, like offices, EV charging stations, lounge etc. By using these X Labs two main scenarios will be tested.

Scenario 1 emulate the case of medium commercial building with PV, V2G and storage. The commercial building is the real Enel office located inside X Lab, particularly:

- Real Enel office (up to 360 kW available power).
- 132 kVA – 274 kWh Li-Ion EESS from X Lab 5.
- 102 kWp PV plant with innovative bifacial Enel3SUN panels, that can reach 125 kWp in bifacial way from X Lab 5.
- EV Charger V2G 20 kVA.

Scenario 2 emulate the case of a summarization of small building with V2G and hybrid PV+storage:

- Regenerative grid simulators from X Lab 1 and X Lab 3 to simulate residential and C&I buildings up to 25 kVA each.
- 24 kWp cumulated photovoltaic (PV) plant (that can reach 29 kWp in bifacial way) hybridized with 20 kWh Li-Ion EESS from X Lab 1.
- Two 3.7 kWp cumulated photovoltaic (PV) plant (that can reach 4.5 kWp in bifacial way) hybridized with 5 kWh Li-Ion EESS from X Lab 3.
- EV Charger V2G 20 kVA.

3.4.7 List of variables:

In this section, a tentative list of potential variables suitable to determine indicators or variable which will be used for providing Flexibility services.
Example table is provided below:

- Real Enel office (up to 360 kW available power).
    - Active power measure.
    - Reactive power measure.
    - Voltage measure at the building terminal.
    - Frequency measure at the building terminal.
- 132 kVA – 274 kWh Li-Ion EESS from X Lab 5.
    - EESS availability state.
    - Active power measure.
    - Reactive power measure.
    - Voltage measure at the building terminal.
    - Frequency measure at the building terminal.
    - State of charge (SOC).
    - State of health (SOH).
    - Minimum SOC for discharge.
    - Maximum SOC for charge.
    - Active power set point.
    - Reactive power set point.
- 102 kWp PV plant with innovative bifacial Enel3SUN panels, that can reach 125 kWp in bifacial way from X Lab 5.
    - Active power measure.
    - Reactive power measure.
    - Voltage measure at the building terminal.
    - Frequency measure at the building terminal.
- EV Charger V2G 20 kVA.
    - V2G availability state.
    - Active power measure.
    - Reactive power measure.
    - Voltage measure at the building terminal.
    - Frequency measure at the building terminal.
    - State of charge (SOC).
    - State of health (SOH).

  - Minimum SOC for discharge.
  - Maximum SOC for charge.
  - Active power set point.
  - Reactive power set point.

- Regenerative grid simulators from X Lab 1 and X Lab 3 to simulate residential and C&I buildings up to 25 kVA each.
  - Active power measure.
  - Reactive power measure.
  - Voltage measure at the building terminal.
  - Frequency measure at the building terminal.

- 24 kWp cumulated photovoltaic (PV) plant (that can reach 29 kWp in bifacial way) hybridized with 20 kWh Li-Ion EESS from X Lab 1.
  - EESS availability state.
  - PV availability state.
  - Active power measure.
  - Reactive power measure.
  - PV Active power measure.
  - EESS Active power measure.
  - Voltage measure at the building terminal.
  - Frequency measure at the building terminal.
  - State of charge (SOC).
  - State of health (SOH).
  - Minimum SOC for discharge.
  - Maximum SOC for charge.
  - Active power set point.
  - Reactive power set point.

- Two 3.7 kWp cumulated photovoltaic (PV) plant (that can reach 4.5 kWp in bifacial way) hybridized with 5 kWh Li-Ion EESS from X Lab 3.
  - EESS availability state.
  - PV availability state.
  - Active power measure.
  - Reactive power measure.
  - PV Active power measure.
  - EESS Active power measure.
  - Voltage measure at the building terminal.
  - Frequency measure at the building terminal.
  - State of charge (SOC).
  - State of health (SOH).
  - Minimum SOC for discharge.
  - Maximum SOC for charge.
  - Active power set point.
  - Reactive power set point.

3.4.7.1 PV Controlling and BESS Monitoring and Variables:

In this section, the main variables used for normal operation and calculation of KPI for PV and BESS systems are presented.

Table 10: List of PV and BESS main variables

LAB 5	Variable	Unit	R/W
Virtual POD (building)	Power	kW	R
	Energy	kWh	R
PV:3SUN Bifacial	Power	kW	R
102 kWp up to 125kWp	Energy	kWh	R
Storage Socomec ESS LG/ 132 kVA – 274 kWh / Li-Ion electrical energy storage system (EESS)	Power	kW	R
	Energy	kWh	R
	State of Charge	%	R
	Control setpoint (P)	kW	RW
	Control setpoint (Q)	kVA	RW
LAB 1			
PV:3SUN Bifacial	Power	kW	R
2X12kWp up to 14,5kWp	Energy	kWh	R
Storage	Power	kW	R
Pylontec	Energy	kWh	R
4X2,4kWh	State of Charge	%	R
LI-ION	Control setpoint	kW	RW

3.4.7.2 List of EVs monitoring and controlling Variables:

In this part of the report, the main variables used for normal operation and calculation of KPI for EV systems are presented.

Table 11: EVs available monitoring variables.

Name	Reg. no.	Type	Unit	Description	Range
SerialN	10	Uint8_t	-	V2G Charging Station Serial Number	-
SWversion	10	Uint8_t	-	V2G Charging Station SW version	-
Veh_Conn_Status	1	Uint16_t	enum	0: Not connected 1: connected	0-1
Min_Charge_current	1	Uint16_t	A	Minimum charge current accepted by EV	0-40
Max_Charge_current	1	Uint16_t	A	Maximum charge current accepted by EV	0-40
Max_Battery_Voltage	1	Uint16_t	V	Maximum battery voltage supported by the EV	50-500
Target_Battery_Voltage	1	Uint16_t	V	Target battery voltage of the EV	50-500
Min_Discharge_Voltage	1	Uint16_t	V	Minimum voltage the EV battery could reach	50-500

Initial_SOC	1	Uint16_t	%	EV SOC at the beginning of the process	0-100
minSOC	1	Uint16_t	%	Min SOC EV could accept during the session	0-100
maxSOC	1	Uint16_t	%	Max SOC EV could accept during the session	0-100
CHAdeMO_version	1	Uint16_t	enum	0: CHAdeMO not compatible 1: CHAdeMO_VER_0_9 2: CHAdeMO_VER_1_0_1	0-2
V2H_version	1	Uint16_t	enum	0: V2H_VER_1_0 1: V2H_VER_2_0_CHA_0_9 2: V2H_VER_2_0_CHA_VER_1_0_1 255: V2H_NOT_COMPATIBLE	0-2
Total_Battery_Capacity	2	Uint32_t	Wh	EV total battery capacity	0-200000
Charge Command	1	Uint16_t	Enum	Active charge mode 0: normal charge 1: V2G_Pause 2: V2G_Charge 3: V2G_Discharge	
Meter_Year	1	Uint16_t	-	Year of the meter timestamp	0-65535
Meter_Month	1	Uint16_t	-	Month of the meter timestamp	0-12
Meter_Day	1	Uint16_t	-	Day of the meter timestamp	0-31
Meter_Hour	1	Uint16_t	-	Hour of the meter timestamp	0-23
Meter_Minute	1	Uint16_t	-	Minute of the meter timestamp	0-59
Meter_Seconds	1	Uint16_t	-	Seconds of the meter timestamp	0-59
Energy active export register	2	Uint32_t	Wh	Energy exported by EV	-
Energy active import register	2	Uint32_t	Wh	Energy imported by EV	-
Energy active export register grid	2	Uint32_t	Wh	Energy exported by the V2G charger on the grid side	-
Energy active import register grid	2	Uint32_t	Wh	Energy imported by the V2G charger from the grid side	-
Energy reactive export register	2	Uint32_t	VAh	Capacitive reactive energy exported to the grid side	-
Energy reactive import register	2	Uint32_t	VAh	Inductive energy imported from the grid side	-
Power active export	1	Uint16_t	W	Instantaneous active power exported by the V2G charger to the grid	
Power active import	1	Uint16_t	W	Instantaneous active power imported by the V2G charger from the grid	
Power reactive export	1	Uint16_t	W	Instantaneous reactive power exported by the V2G charger to the grid	
Power reactive import	1	Uint16_t	W	Instantaneous reactive power imported by the V2G charger from the grid	

Current export	1	Uint16_t	dA	Instantaneous current flow to the grid multiplied by 10	
Current import	1	Uint16_t	dA	Instantaneous current flow from the grid multiplied by 10	
Grid Voltage	1	Uint16_t	dV	Grid RMS voltage value multiplied by 10	
Temperature	1	Uint16_t	°C	Temperature inside the V2G Charging Station	
Charger Action	1	Uint16_t	enum	Charge mode being performed by the V2G charging station 0: normal charge 1: V2G_Pause 2: V2G_Charge 3: V2G_Discharge	
DC Voltage	1	Uint16_t	V	EV battery voltage	0-500
Current battery SOC	1	Uint16_t	%	Current SOC of the EV	0-100
Charge time	2	Uint32_t	s	elapsed time	
Estimated charging time	2	Uint32_t	s	Estimated time to finish the charge	
Frequency	1	Uint16_t	Hz	Electric grid frequency multiplied by 100	

Table 12: Available EVs controlling variables.

Name	Reg. no.	Type	Unit	Description	Range
Charger command	1	Uint16_t	Enum	Charge mode to be performed by the V2G Charging Station 0: normal charge 1: V2G_Pause 2: V2G_Charge 3: V2G_Discharge	
minSOC	1	Uint16_t	%	Minimum SOC the EV has to reach in V2H_Discharge mode	0-100
maxSOC	1	Uint16_t	%	Maximum SOC the EV has to reach in V2H_Charge mode	0-100
ActiveCurrent Setpoint	1	Uint16_t	A	Current setpoint the V2G charging station has to use during the activity	0-40
ActivePower Setpoint	1	Uint16_t	W	Active Power setpoint the V2G charging station has to use during the activity	0-15000
ReactivePower Setpoint	1	Uint16_t	W	Reactive Power setpoint the V2G charging station has to use during the activity	0-15000
Validity Flags	1	Uint16_t	-	Bit0=1 à ActiveCurrentSetpoint contains a valid value Bit1=1 à ActivePowerSetpoint contains a valid value Bit2=1 à ReactivePowerSetpoint contains a valid value	

3.5 Generic structure in Residential EMS

As part of the InterSTORE project, the use of new smart-energy communication standards (such as IEEE 2030.5) is being implemented on Eaton's Brightlayer Home EMS. In addition, a core objective of the project is the development of generic interfaces for the integration of DER from third-party suppliers. This includes not only purely electrical resources but other energy assets, such as thermal units (CHP systems and heat pumps). Specifically, the integration of two battery storage systems (one each in the high-energy and high-power categories), distributed photovoltaic systems with various inverters, and heat pump systems and thermal storage units are planned as part of the demonstrations in Living Labs.

The use of thermal resources extends the time scale of optimization functions for simultaneous (but not necessarily synchronous) control of electrical and thermal systems. The feedback reaction times of residential heating resources are in the scale of several minutes (even up to hours). Thus, switching operations on such systems occur much slower and less frequently than on electrical resources such as battery storage, flexible electrical loads or photovoltaic systems.

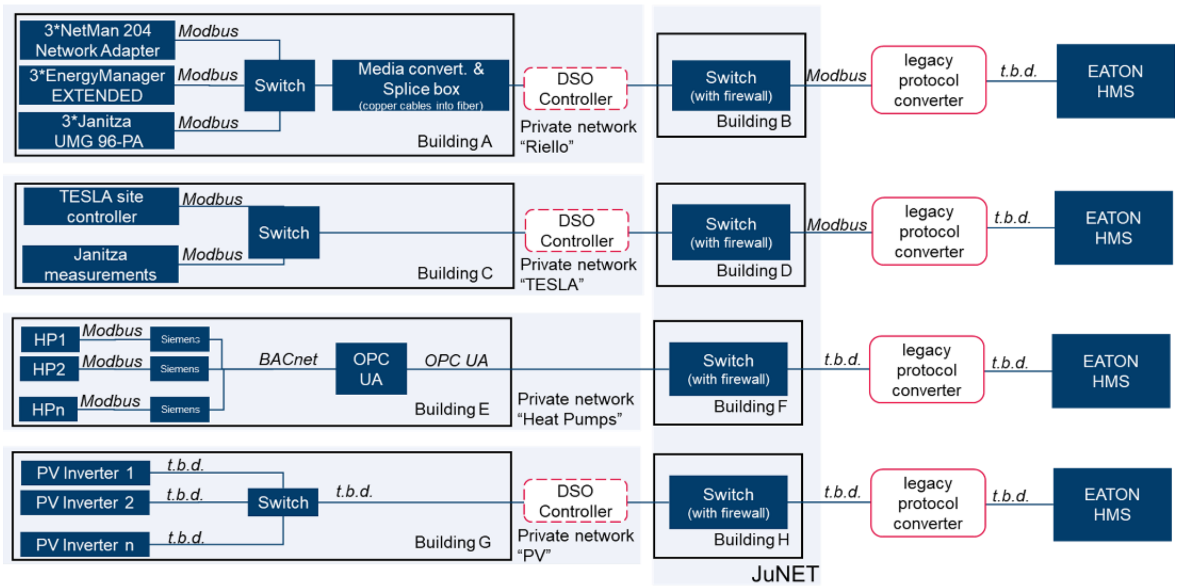

Figure 31. Setup for demonstration of advanced structure of Eaton Brightlayer HMS

Figure 30 shows some of the assets that will be monitored and controlled by Eaton's EMS, and their general connection configuration.

The demonstration includes the monitoring and control of UPS units, through the Netman 204 Network Adapters (in the block called Building A), which are monitoring the temperature and humidity and driving cooling fans or locks. Currently, values are provided via Internet, SNMP and via PowerShield3 software. Eaton's EMS will also connect to the Network Adapters and will include them in the overall management algorithm.

The system includes also additional monitoring and control assets, such that the Energy Manager from Siemens, Janitza UMG 96-PA energy data analysers, and Tesla site controller, which are providing local power quality monitoring and basic energy management. The DER assets to be added to Eaton's EMS scope are several Heat Pumps (as indicated in Building E block) and photovoltaic inverters (Building G block).

Eaton EMS will be extended to include all the assets indicated in figure 30, which will be accessed by the cloud application through firewall protected switches (JuNET). As the energy assets, from various providers, are organized in private networks and implementing different communication standards (Modbus, BACnet, OPC UA), the overall system will include protocol adapters towards Eaton EMS.

Another objective of the activities in the project is to develop, test and validate the parallel operation of multiple instances of the Eaton Building EMS. Additionally, this BEMS may be applied with third-party control units.

3.5.1 List of variables

Table 10 is indicating the proposed potential indicators or variables, which could be used for providing services (energy management and sustainability optimization criteria).

Table 13: Main expected variables to identify the Eaton management system characteristics and operation.

Name / Description	Unit
Integrated measurements	
Accuracy of integrated measurement	%
Cycle of integrated measurements	ms
Total number of connectable devices	Units
Total number of manageable devices	Units
Operational costs	€/kWh
Self sufficiency rate	%
Self consumption rate	%
Prevented curtailment	w/d
Battery degradation reduction	ppm/d
Comfort violations (number)	Number
Comfort violations (amount)	
Start-up time	s
Shut-down time	s
Restart time	s
Black start capability	yes/no
Sleep mode option (available or not)	yes/no
Temperature range (working)	°C
Temperature range (shelf)	°C
Humidity range (RH%)	RH%
Fluids emissions (rate, composition, risks)	various
Noise emissions	dB
Heat emissions	kW
Electromagnetic emissions	dBµV/m
Other emissions	various
Expected lifetime	year
Expected maintenance indicator (e.g. MTBF)	month
Lifetime measurements indicators	year
Availability indicators (module/rack/container level)	enumeration
Self consumption	W
Number of monitoring parameters, digital I/O for signaling	/
Communication lines/protocols	enumeration

Protocols interface for third parties communications (monitoring, supervision): e.g. open protocol, API availability, server requests availability, and so on. At all level: BMS/ Master BMS	enumeration
Compliance with national or international standards/certifications	enumeration
Standard solicitation profiles for power/energy application (Voltage, current, SOC, Temperature, SOH)	enumeration

Table 14: List of common variables to identify current or suggested available devices for system development

Currently available or suggested devices (within partner development/production) typical variables of interest	Unit
Electrical nominal power/energy value(s)	kW, kWh
Modularity	kWh/rack
Max. Charge/Discharge Current (DC)	A
Electrical connections interfaces (number, types, and power capability): DC	enumerated
Electrical connections interfaces (number, types, and power capability): AC	enumerated
Round-trip Efficiency	%
Total harmonic distortion (THD)	%
Communication protocols	enumerate
Communication interfaces	enumerate
Islanding capability	yes/no
Battery Chemistry	n/a
Warranty	years
Compliance with national or international standards/certifications	n/a
Dimensions	mm x mm x mm
Weight	kg
IP Protection class	
Ambient conditions: Temperature	°C
Ambient conditions: Humidity	%
Ambient conditions: Pollution	
Ambient conditions: Altitude	m
Clearances	mm
Mounting method	
Enclosure material	
Earth fault protection	
Charge and discharge curve specifications (function of SOC, T, C or P rate, SOH, …)	enumerated
Charge and discharge limitation specifications (function of SOC, T, C or P rate, SOH, …)	enumerated
Electrical grounding / earthing recommendations and schemes	enumerated
Additional available signals for external/remote supervision and control	enumerated
Additional required signals for external/remote supervision and control	enumerated
Calendar & Cyclic ageing performances at cell/module/rack battery level (test data; function of SOC, T, C or P rate, SOH, …)	enumerated (BoL value, decay rate)

4 CONCLUSION

The present deliverable report collected the main generic specifications of different EMS tools from different partners of the InterSTORE project. It gathered and introduced the main functionalities, hybrid system development, interfaces of the control architecture and services that each of the EMS is providing at the moment and listed which new services will be developed during the project.

Overall the report has been written in 4 chapters. In chapter 2, the core of the hybridization concept, which is going to be used with different applications on several use cases, has been presented and explained. It shows how a wide range of services can be provided by hybridizing different storage technologies. Then, chapter 3 and 4 are devoted to exploring the main functionalities and specification of different EMS tools. Chapter 3 presents the current available technology for each different partner. While chapter 4 mainly focused on the new advances with respect to the InterSTORE project.

Here is the summary of the main presented EMS tools on this deliverable:

- CyberNoc Flexibility management platform:

Advanced software system which can be used by aggregators and traders of flexibility electricity. Thanks to its advancement in the project, it can enables seamless and cost-efficient integration of BESS and other flexibilities with multiple European electricity markets through standardized interfaces.

- Hybrid Distributed Energy Management System (HyDEMS):

HESStec's energy management systems, comprised by UCMS (energy storage management system), InMS-SHAD (hybrid energy storage integration, grid stability and fast response capability) and InMS (Intelligent node management system, grid assets optimization, and multiservice operation in renewable, DSO/TSO and microgrids applications). HESStec, in InterSTORE project, will focus its effort on the definition of the specifications of a new generation of distributed and hybrid energy management systems, as well as in the integration of interoperable tools, such as HESStec's State of Function, a virtualization layer for the grid operation based on a dimensionless vector that shows, on a very compact way, the availability of a DES to perform multiple and simultaneous flexibility services.

- Home Energy Management System (HEMS):

INSECtec's Home Energy Management System as its state of the art is a tool to enable flexibility provision from home, working with diverse appliances such as washing machines or heat pumps. Its main functions are monitoring and data analytics on energy usage; optimal scheduling of flexible assets to provide demand side flexibility support. In terms of variables and Time steps, the system functions are mainly energy and power from several flexible assets (e.g., controllable loads, microgeneration, etc.) as well as load profiles for optimization and decision support in configurable time horizons (e.g. 15 min or lower). During InterSTORE project, InescTec will adapt its energy management system (HEMS) to a context where hybrid storage systems are combined. The system will evolve to a modular and computer-effective cloud-based solution, in order to integrate semantically interoperable services, such as forecasting, energy flexibility, optimization, etc. It will be able to retrieve existing sensor data as identified in the trends and any existing disaggregated data (such as from meter dongles). It will communicate with the DEMS Via semantic registers through standardised communication interfaces and adapted to eventual OPEN-SOURCE interoperable tools developed in InterSTORE.

- Hybrid E-mobility Management platform:

InterSTORE will contribute to the advance the current DES & DER offered by ENELX, by leveraging the standardised protocol to increase the number of supported hybrid DERs (e.g. PVs, load, BESS, and EVs.). With the InterSTORE project, the Platform will evolve to Hybrid Management Platform with the introduction of the concept of VPP (Virtual power Plant) Manager and the Asset Manager. In this case, the VPP Flex platform will have a new level of abstraction thanks to the Asset manager, and the VPP Flex platform will become independent and more scalable from the specific device typology.

With this architecture, it will be possible to build a business portfolio that leverage on different kinds of devices to satisfy the market needs and to achieve the highest revenues from Flex Services.

- Residential Power Management System (EATON):

The energy management system for residential/commercial buildings is part of Eaton's Brightlayer platform. The Brightlayer platform offers a comprehensive software solutions and services targeted to key industries/applications such as utilities, data-centers, industrial production and buildings. As part of the InterSTORE project, the use of new smart-energy communication standards (such as IEEE 2030.5) is being implemented on Eaton's Brightlayer HEMS. In addition, a core objective of the project is the development of generic interfaces for the integration of DER from third-party suppliers. Considering the updates and developments during the project it is expected to improve also the time scale of optimization process of electrical and thermal systems, switching actions with full testing and validation of the parallel operation of multiple instances of the Eaton BEMS.

5 REFERENCES

Chapter no.	Title	Source(s)
3.1	CyberGrid- CyberNoc	https://www.cyber-grid.com/platform
3.2	HESStec-InMS	https://hesstec.net/?page_id=152
3.3	Inesctec - HEMS	https://www.inesctec.pt/en
3.4	EnelX - Hybrid E-mobility Service	https://www.enelx.com/ro/en/clienti-re-zidentiali/mobilitate-electrica
3.5	MQTT- Message Queuing Teleme-try Transport Secured	https://en.wikipedia.org/wiki/MQTT
3.6	Kafka broker	https://kafka.apache.org/documentation/
3.7	EATON - Brightlayer platform	https://www.eaton.com/us/en-us/digi-tal/brightlayer.html

Table 15: List of references.

6 LIST OF TABLES

7 LIST OF FIGURES